DOCUMENT RESUME

ED 082 972 SE 016 481

AUTHOR McElhattan, Glenn R.
TITLE Development of an Auto-Instructional Approach for the Individualization of Instruction in a College Physical Science Course for Prospective Elementary Teachers. Final Report.
INSTITUTION Clarion State Coll., Pa.
SPONS AGENCY National Center for Educational Research and Development (DHEW/OE), Washington, D.C. Regional Research Program.
BUREAU NO BR-2-C-012
PUB DATE Jun 73
GRANT OEG-3-72-0016
NOTE 196p.

EDRS PRICE MF-$0.65 HC-$6.58
DESCRIPTORS *Autoinstructional Programs; *College Science; Curriculum Development; Educational Research; *Elementary School Teachers; *Individualized Instruction; *Physical Sciences; Science Education; Teacher Education
IDENTIFIERS Research Reports

ABSTRACT

The purpose of this study was to develop and evaluate an auto-instructional individualized physical science (chemistry) course appropriate for prospective elementary school teachers. Thirteen core and several optional lessons were developed using guidelines and standards proposed by the Commission on Science Education of the American Association for the Advancement of Science. Each lesson consisted of a lesson guide which included instructional objectives, readings, film loops, filmstrips, written exercises, investigations, self-contained readings, and guide sheets. Students worked alone or in small groups at their own pace. The course was pilot tested at Venango Campus, Clarion State College, Oil City, Pennsylvania, during the January-May 1972 semester. Revisions were made, and the course was evaluated during the September-December 1972 semester. Pertinent findings include: (1) a significant improvement between pretest and posttest scores on the Test on Understanding Science, and (2) a significant improvement between pretest and posttest scores on the Processes of Scientific Inquiry Inventory. All students in the course exceeded the minumum criterion score on the Science Content Test. A large majority of the students preferred the individualized approach. (Author/JR)

FILMED FROM BEST AVAILABLE COPY

ED 084972

Final Report

U.S. DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION
THIS DOCUMENT HAS BEEN REPRO-
DUCED EXACTLY AS RECEIVED FROM
THE PERSON OR ORGANIZATION ORIG-
INATING IT. POINTS OF VIEW OR OPIN-
IONS STATED DO NOT NECESSARILY REPRE-
SENT OFFICIAL NATIONAL INSTITUTE OF
EDUCATION POSITION OR POLICY

Project No. 2-C-012
Grant No. OEG-3-72-0016

SCOPE OF INTEREST NOTICE
The ERIC Facility has assigned this document for processing to:

In our judgement, this document is also of interest to the clearinghouses noted to the right. Indexing should reflect their special points of view.

Glenn R. McElhattan
Clarion State College
Clarion, Pennsylvania 16214

DEVELOPMENT OF AN AUTO-INSTRUCTIONAL APPROACH FOR THE INDIVIDUALIZATION OF INSTRUCTION IN A COLLEGE PHYSICAL SCIENCE COURSE FOR PROSPECTIVE ELEMENTARY TEACHERS

June 1973

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development
(Regional Research Program)

SE 016 481

ABSTRACT

DEVELOPMENT OF AN AUTO-INSTRUCTIONAL APPROACH FOR THE INDIVIDUALIZATION OF INSTRUCTION IN A COLLEGE PHYSICAL SCIENCE COURSE FOR PROSPECTIVE ELEMENTARY TEACHERS

The purpose of this study was to develop and evaluate an auto-instructional individualized physical science (chemistry) course appropriate for prospective elementary school teachers. Thirteen core and several optional lessons were developed using guidelines and standards proposed by the Commission on Science Education of the American Association for the Advancement of Science. Each lesson consists of a lesson guide which includes instructional objectives, readings, film loops, filmstrips, written exercises, investigations, self-contained readings, and guide sheets. Students work alone or in small groups at their own pace.

The course was pilot tested at Venango Campus, Clarion State College, Oil City, Pa. during the January-May 1972 semester. Revisions were made, and the course was evaluated during the September-December 1972 semester.

Pertinent findings include: a significant improvement between pre-test and post-test scores on the Test On Understanding Science; a positive group mean score on the Survey of Attitudes and Opinions on Science and Scientists; and a significant improvement between pre-test and post-test scores on the Processes of Scientific Inquiry Inventory. All students in the course exceeded the minimum criterion score on the Science Content Test. A large majority of the students preferred the individualized approach.

Final Report

Project No. 2-C-012
Grant No. OEG-3-72-0016

DEVELOPMENT OF AN AUTO-INSTRUCTIONAL APPROACH FOR THE INDIVIDUALIZATION OF INSTRUCTION IN A COLLEGE PHYSICAL SCIENCE COURSE FOR PROSPECTIVE ELEMENTARY TEACHERS

Glenn R. McElhattan

Clarion State College

Clarion, Pennsylvania 16214

June 1973

The research reported herein was performed pursuant to a grant with the Office of Education, U.S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgement in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development
(Regional Research Program)

PREFACE

The auto-instructional individualized physical science course described herein is similar in some respects to individualized courses developed recently at many institutions. It may be unique in some of the management techniques it employs, in some of the instructional materials developed, and in the placing of as much emphasis on inquiry skills and attitudes as is placed on science content.

My thanks are extended to the copyright holders of the Test On Understanding Science, form W, copyright 1961, by W. W. Cooley and L. E. Klopfer, for granting permission to use this instrument in the study and include it in this report.

I would like to acknowledge the generous financial assistance provided by the U.S. Office of Education and Clarion State College.

My deepest thanks are extended to Dr. Leo E. Klopfer, Director of the Individualized Science Program of the Learning Research and Development Center at the University of Pittsburgh for his expert advice and counsel throughout the project. Many others assisted in the project by offering advice and criticism, by acting as judges during the development of instruments, and in many other ways. They include Doctors Audrey Champagne, Willard Korth, Vernon Lingren, Albert Nous, and Robert Wolke at the University of Pittsburgh. Those who assisted from Clarion State College include Doctors Frank Battista, Donald Morgan, Ken Mechling, John Laswick, and several members of the Graphic Arts Section of the Division of Communication.

TABLE OF CONTENTS

		Page
LIST OF TABLES		vi
Chapter		
I.	REVIEW OF RELATED LITERATURE	1
	Chemistry Courses for Non-Science Majors	2
	Curriculum Development Groups	3
	Teaching Methods in the Physical Sciences	3
	Individualized Instruction	5
	Advantages of Individualized Instruction	6
	Summary	8
II.	THE PROBLEM	10
	The Nature of the Problem	10
	Statement of the Problem	12
	Objectives of the Study	14
	Hypotheses	14
	Procedure	15
III.	DEVELOPMENT OF THE AUTO-INSTRUCTIONAL COURSE AND THE ASSESSMENT INSTRUMENTS	17
	Introduction	17
	Development of the Auto-Instructional Lessons	20
	Management Techniques	22
	Student Feedback Instruments	24
	Formative Evaluation Findings	25
	Student Log Sheets	25
	Student Response Sheet	26
	Course Appraisal	28
	Other Formative Evaluation Findings	31
	Formative Evaluation Summary	32
	Revisions and Additions	32
	Test Instruments	35
	Test On Understanding Science	35
	Survey of Attitudes and Opinions on Science and Scientists	35
	Processes of Scientific Inquiry Inventory	37
	Science Content Test	37

IV. EVALUATION OF THE REVISED AUTO-INSTRUCTIONAL COURSE . . . . . Page 39

Introduction 39
Effectiveness of the Auto-Instructional Course 39
Appreciation for Science 40
Attitude Toward Science and Scientists 43
Processes of Scientific Inquiry 44
Science Content 47
Acceptability of the Course 48
Feasibility and Manageability of the Course 51
Summary 53

V. SUMMARY, CONCLUSIONS, AND DISCUSSION 54

Summary of Findings 55
Conclusions 55
Discussion 56
Summary 58

BIBLIOGRAPHY 59

APPENDICES 65

A. SAMPLE INSTRUCTIONAL MATERIALS 66

Auto-Instructional Lesson Guides 67
Lesson 1. What is Science? 70
Lesson 6. Heat: Fluid or Motion 78
Lesson 13. The Detergent Dilemma 96
Optional Lessons: Science and Society 105
Instructional Objectives 117

B. STUDENT FEEDBACK INSTRUMENTS 123

Student Log Sheet: Lesson 1 124
Student Response Sheet 125
Course Appraisal 126

C. TEST INSTRUMENTS 128

Test On Understanding Science 129
Survey of Attitudes and Opinions on Science and Scientists 143
Processes of Scientific Inquiry Inventory 147
Science Content Test 155

D. ADDITIONAL TABLES 180

Table 18: Student Behavior Categories, Correct Responses, and Incorrect Responses for Pre-Test and Post-Test POSII Items 181

Page

Table 19: Instructional Objectives, Correct Responses, and Incorrect Responses, for Unit I SCT Items 182

Table 20: Instructional Objectives, Correct Responses, and Incorrect Responses for Unit II SCT Items 183

Table 21: Instructional Objectives, Correct Responses, and Incorrect Responses for Unit III SCT Items 184

Table 22: Instructional Objectives, Correct Responses, and Incorrect Responses for Unit IV SCT Items 185

Table 23: Identification of Items by Scales for the SAOSS 186

LIST OF TABLES

Table		Page
1.	Unit and Lesson Topics: Phase I	19
2.	Student Behavior Categories	20
3.	Weekly Time Schedule for Use of the Classroom Laboratory	23
4.	Time Spent on Lessons	25
5.	Summary of Student Response Sheets	27
6.	Course Appraisal: Summary of Responses	29
7.	Unit Topics, Lesson Topics, and Types of Instructional Materials Employed	34
8.	Comparison of Pre-test and Post-test Scores on TOUS	41
9.	Chi Square Values for TOUS Items	42
10.	Numbers of TOUS Items with Significant Improvement	43
11.	Group Mean Scores on the SAOSS	44
12.	Comparison of Pre-test and Post-test Scores on POSII	45
13.	Chi Square Values for POSII Items	46
14.	Number of POSII Items with Significant Improvement	47
15.	Distribution of Scores on the SCT	48
16.	Summary of Student Response Sheets: Phase II	49
17.	Summary of Responses on the Course Appraisal: Phase II	51
18.	Student Behavior Categories, Correct Responses, and Incorrect Responses for Pre-test and Post-test POSII Items	181

19. Instructional Objectives, Correct Responses, and Incorrect Responses for Unit I SCT Items . . . . . Page 182

20. Instructional Objectives, Correct Responses, and Incorrect Responses for Unit II SCT Items 183

21. Instructional Objectives, Correct Responses, and Incorrect Responses for Unit III SCT Items 184

22. Instructional Objectives, Correct Responses, and Incorrect Responses for Unit IV SCT Items 185

23. Identification of Scales by Items for the SAOSS 186

CHAPTER I

REVIEW OF RELATED LITERATURE

> The task is clear. The task is huge. The time is horribly short. In the past we have had science for intellectual pleasure and science for the control of nature. We have had science for war. But today, the whole human experiment may hang on the question of how fast we now press the development of science for survival.[1]

The study described in this dissertation involves the development and evaluation of a chemistry-oriented physical science course designed to serve as an appropriate part of the preparation program for elementary school teachers. Accordingly, the literature review focuses on studies most relevant to the development of this type of course. The studies reviewed will be grouped into several topics that relate to the past and present offerings in college level physical science courses and to certain significant influences and trends which led to the type of course subsequently developed.

The importance of including sound science programs in elementary schools has been recognized in recent years. In a plenary address to the 1970 International Conference on Education in Chemistry, Hornig states, " . . . the time to instill the language of science, the basic facts and principles of science, and the basic attitudes of science is in the elementary school years. . . ."[2] This can only happen if the

---

[1]John Platt, "What We Must Do," Science, CLXVI (28 November 1969), p. 1121.

[2]Donald Hornig, "New Problems Need New Answers," Journal of Chemical Education, XLVIII (January, 1971), p. 33.

preparation programs for elementary school teachers include science courses which adequately equip them to play a meaningful role in presenting new elementary school science programs to children.

Chemistry Courses for Non-Science Majors

Many prospective elementary school teachers receive part of their science content preparation in a chemistry course for non-science majors. In 1942, Alyea stated that " . . . for the beginner who will probably not continue in chemistry, curiosity and judgement are paramount, while knowledge is merely of transient importance."[1] Goldsmith in 1968 reported on the topics most commonly included in physical science (chemistry) courses.[2] After surveying 500 colleges and universities, Dodson reported a need for a separate introductory chemistry course for non-science majors.[3] In 1968 Kieffer described a chemistry course for non-science majors which is concerned more with how a scientist thinks about the universe, the relevance of topics, and the social aspect of chemistry, than with the amount of factual material included.[4] In 1970 Wolke reported on a similar course at the University of Pittsburgh.[5]

---

[1]Hubert N. Alyea, "The Function of General Chemistry," Journal of Chemical Education, XVIII (July, 1941), p. 310.

[2]Robert H. Goldsmith, "Chemical Content of the Physical Science Course," Journal of Chemical Education, XLIV (October, 1967), pp. 579-580.

[3]B. C. Dodson, A Survey of the Teaching Practices and Materials Used in Introductory College Chemistry, Office of Education Report, (August, 1968), p. 19.

[4]William F. Kieffer, "Chemistry, Curiosity, and Culture," Journal of Chemical Education, XLV (September, 1968), pp. 550-555.

[5]Robert L. Wolke, "Chemistry for the Non-Science Major," Journal of Chemical Education, XLVII (December, 1970), pp. 788-793.

He suggests including topics such as pollution, fallout hazards, scientific research, how chemists communicate, and studies of scientific controversies.

Curriculum Development Groups

Several recent curriculum study groups have developed materials for college physical science courses. A group headed by Parsegian has integrated the biological and physical sciences in a two year program.[1] The project headed by Puri integrates physical, earth, and space science.[2] Haber-Schaim's group has developed an integrated text and laboratory manual.[3] One of the most promising efforts is the Physical Science for Non-Science Majors (PSNS) project headed by Bassett.[4] It uses matter in the solid state as the unifying concept. The extent of most of these projects is the development of texts, teacher's guides, and laboratory materials. Little or no provision is made for individual differences. Evaluation has been very limited.

Teaching Methods in the Physical Sciences

Many studies have been concerned with the teaching methods employed in college physical science courses. Miller found that taped lectures could be efficiently employed, especially for those students

---

[1]V. Lawrence Parsegian, et. al., Introduction to Natural Science, (New York, 1968), pp. 1-727.

[2]O. P. Puri, et. al., Concepts in Physical Science, (Reading, Mass., 1970), pp. 1-399.

[3]Uri Haber-Schaim, et. al., College Introductory Physical Science, (Englewood Cliffs, N. J., 1969), pp. 1-306.

[4]Lewis G. Bassett, et. al., PSNS/An Approach to Physical Science, (New York, 1969), pp. 1-534.

with high ability.[1] Robinson found that effective use of science articles could promote science understanding and an improvement in attitude.[2] Zitelli found no advantage in having a specialist in the discipline teach each major area in a physical science course.[3] Smith found science instruction related to life situations benefitted those with disadvantaged backgrounds.[4]

The laboratory in physical science has also received much attention. Weaver distinguished six essential criteria for experiments in physical science.[5] Mattheis found the science project approach superior to conventional replication-verification lab exercises for those students with a high science interest.[6] Hiack devised a series of experiments appropriate for prospective elementary school teachers and emphasizing the

---

[1]Raymond E. Miller, "A Study of the Effects of Three Methods on the Learning of Selected Topics in a College Physical Science Course" (Unpublished Doctoral Dissertation, Pennsylvania State University, 1962), Dissertation Abstracts, XXIII (1963), 2450.

[2]Jack H. Robinson, "Effects of Teaching With Science Articles," Science Education, XLVII (Februrary, 1963), pp. 73-83.

[3]Patsy A. Zitelli, "An Evaluation of a Cooperative Teaching Method in Basic Physical Science as Required of Non-Science Majors," Science Education, LI (April, 1967), pp. 295-298.

[4]Charlie J. Smith, "A Comparative Study of Two Methods of Teaching of Physical Science to College Freshman with Disadvantaged Backgrounds" (Unpublished Doctoral Dissertation, University of Mississippi, 1970), Dissertation Abstracts, XXXI (1970), 1152A.

[5]Allen D. Weaver, "A Determination of Criteria for Selection of Laboratory Experiences Suitable for an Integrated Course in Physical Science Designed for the Education of Elementary School Teachers" (Unpublished Doctoral Dissertation, New York University, 1954), Dissertation Abstracts, XV (1954), 238.

[6]Floyd E. Mattheis, "A Study of the Effects of Two Different Approaches to Laboratory Experiences in College Science Courses for Prospective Elementary Teachers" (Unpublished Doctoral Dissertation, University of North Carolina, 1962), Dissertation Abstracts, XXIII (1963), 4616.

process approach of the American Association for the Advancement of Science (AAAS) elementary school science program.[1] Jones suggested that a non-lab physical science course does not produce significant gains in attitude or critical thinking ability.[2] Stekel found that increasing student involvement in the design of experiments leads to a significant improvement in the students' understanding of the actions and operations of scientists.[3]

Individualized Instruction

Individualized instruction has been hailed by many individuals and agencies as an effective and useful instructional procedure. The early efforts at developing programs of this type have been concentrated primarily in the elementary and secondary schools. Among studies conducted at the elementary school level are those reported by Ramsey and Wiandt, O'Toole, Gallagher, and Klopfer.[4] Studies of individ-

---

[1]Paul S. Hiack, "Laboratory Experiments in College Physical Science for Prospective Elementary School Teachers" (Unpublished Doctoral Dissertation, Columbia University, 1966), Dissertation Abstracts, XXVII (1967), 2915A.

[2]Haskell L. Jones, "The Development of Certain Aspects of Scientific Literacy in College Freshman Physical Science Students" (Unpublished Doctoral Dissertation, Ohio State University, 1969), Dissertation Abstracts, XXX (1969), 1337A.

[3]Frank D. Stekel, "The Effects of Increasing the Student Involvement in a College Physical Science Laboratory Program" (Unpublished Doctoral Dissertation, Indiana University, 1970), Dissertation Abstracts, XXXI (1971), 5880A.

[4]Irvin L. Ramsey and Sandra L. Wiandt, "Individualizing Elementary Science," School Science and Mathematics, LXVII (May, 1967), pp. 419-427; Raymond J. O'Toole, "A Review of Attempts to Individualize Elementary School Science," School Science and Mathematics, LXVIII (May, 1968), pp. 385-390; James J. Gallagher, "A Comparison of Individualized and Group Instruction in Science," Journal of Research in Science Teaching, VII (1970), pp. 253-263; Leopold E. Klopfer, "Individualized Science in Focus," (unpublished paper presented to the Illinois State Academy of Science, 1971).

ualized instruction in the secondary school include those by Finley, Engel and Torgenson, Arena, and Rasmussen.[1]

One of the early attempts to individualize a college science course was the use of audio-tapes in a botany course by Postlethwait.[2] Siemankowski found a significantly higher achievement in the geology and astronomy portions of a college physical science course using auto-paced instruction. He also found a significant improvement in attitude.[3] Other significant attempts at individualizing college science courses include courses in introductory physics, elementary science methods, and a physical science course synthesizing materials from Introductory Physical Science (IPS) and PSNS.[4]

Advantages of Individualized Instruction

Many advantages of individualized instruction have been cited. Among other positive practices for learning, Mager lists:

---

[1]Albert C. Finley and H. M. Louderback, "A Different Kind of High School," The Science Teacher, XXXIV (October, 1967), pp. 46-48; Dorothy Engel and K. J. Torgenson, "Individualized Science With Behavioral Objectives," The Science Teacher, XXXVII (November, 1970), pp. 22-23; John E. Arena, "An Instrument for Individualized Instruction," Educational Leadership, XXVII (May, 1970), pp. 784-787; L. V. Rasmussen, "Individualizing Science Education," Educational Technology, X (January, 1970), pp. 53-56.

[2]S. N. Postlethwait, et. al., An Integrated Experience Approach to Learning With Emphasis on Independant Study, (Minneapolis, 1964).

[3]Francis T. Siemankowski, "An Auto-Paced Teaching Process in Physical Science for Elementary Teacher Preparation: A Pilot Report," Journal of Research in Science Teaching, VI (1969), p. 59.

[4]John S. Rigden, "An Individualized Approach to Introductory Physics," American Journal of Physics, XXXVIII (December, 1970), pp. 1407-1412; Gerald H. Krockover, "On My Own: An Individualized Science Methods Course," Journal of College Science Teaching, I (December, 1971), p. 39; John W. Butzow and Roland Pare, "Physical Science: A Multi-Media Facilitated Course," Journal of College Science Teaching, II (October, 1972), pp. 29-32.

1. Giving the student some choice in selecting and sequencing subject matter . . . thus making positive involvement possible.
2. Providing the student with some control over the length of the instructional session.[1]

Wolfson states that with individualized instruction less emphasis can be placed on conformity and more on initiative and individuality.[2]

Perkins states that the teacher becomes more effective as a facilitator of instruction than in the conventional role, and that through the use of alternate learning experiences and retests the stigma of failure is eliminated.[3] Ramsey and Wiandt report that the pupils are enthusiastic, the slower learners are better able to participate, and the teachers are less reluctant to discuss an area of limited knowledge with one student, rather than the whole class.[4] Lunetta and Odvard cite many advantages of an individualized science program, including the following: the more able students progress faster and can tutor the slower students; not as many laboratory materials are needed as students naturally tend to spread themselves out in rate of progress; the instruction is tailored to the learner; with the assistance of student aides, a master teacher can process more students; and the role of aide is good experience for inexperienced teachers.[5]

---

[1]Robert F. Mager, Developing Attitude Toward Learning, (Belmont, California, 1968), p. 59.

[2]Bernice J. Wolfson, "Pupil and Teacher Roles in Individualized Instruction," The Elementary School Journal, LXVIII (April, 1968), p. 357.

[3]Ronald J. Perkins, "A Structured Independant Study Course in Chemistry," The Science Teacher, XXXVII (November, 1970), p. 19-20.

[4]Ramsey and Wiandt, "Individualizing Elementary Science," pp. 426-427.

[5]Vincent N. Lunetta and Egil D. Odvard, "Individualized Instruction in the Science Curriculum," School Science and Mathematics, LXXI (February, 1971), pp. 126-128.

A study by Nazzaro, et. al., to investigate the relationship of ability to success in an individualized course concluded that both low and high ability students can profit by the individualized approach.[1] Williams reported that students enjoyed individualized instruction more because they were more involved.[2] Klopfer suggests that skills in self-direction and self-evaluation are especially important in these times when a person may have to retrain for several different occupations in his lifetime.[3]

Individualized instruction, as reported in the various studies, can vary significantly in degree. It can involve a highly structured learning sequence in which the only aspect of individualization is the pacing or time required to complete the material. At the other extreme it can allow the student complete freedom in choosing his own objectives and activities. It usually falls somewhere between these extremes.

Summary

The literature review has focused on many studies pertinent to the development of a chemistry-oriented physical science course. A significant number of recent studies have cited the advantages of individualizing instruction. The next chapter describes how an individualized physical science course for prospective elementary school teachers was conceived

---

[1]James R. Nazzaro, Joao C. Todorov, and Jean N. Nazzaro, "Student Ability and Individualized Instruction," Journal of College Science Teaching, II (December, 1972), pp. 29-30.

[2]William W. Williams, "An Experimental Investigation of Individualized Instruction in the Teaching of Quantitative Physical Science" (Unpublished Doctoral Dissertation, Duke University, 1969), Dissertation Abstracts, XXXI (1970), 312A.

[3]Klopfer, "Individualized Science in Focus," p. 3.

and how the study was planned in order to provide for the sound development and evaluation of the course.

CHAPTER II

THE PROBLEM

The Nature of the Problem

The training program for prospective elementary school teachers should include a wide variety of science experiences. In a study to determine why elementary school teachers are reluctant to teach science, Victor concluded that the preparation of these teachers should include both methods courses and basic sciences content courses.[1] According to the Teacher Preparation-Certification Study of the National Association of State Directors of Teacher Education and Certification-American Association for the Advancement of Science (NASDTEC-AAAS),[2] these basic science courses should not only prepare the prospective elementary teacher in science content, but should be conducted in ways which will develop an understanding of processes, scientific inquiry, and mathematical thinking. Unfortunately, few institutions of higher education have science content courses especially designed for elementary school teacher preparation.

According to the AAAS Commission on Science Education report,[3]

---

[1]Edward Victor, "Why Are Our Elementary Teachers Reluctant to Teach Science?" Science Education, XLVI (March, 1962), pp. 190-191.

[2]Guidelines for Science and Mathematics in the Preparation Program of Elementary School Teachers, (AAAS Miscellaneous Publication 63-7, 1963), p. 2.

[3]Preservice Science Education of Elementary School Teachers, (report of the AAAS Commission on Science Education), (AAAS Miscellaneous Publication 70-5, 1970), pp. 11-14.

college science courses for prospective elementary school teachers should be developed which will teach science in the same open inquiry style that is encouraged in elementary school science programs. The adage that "we teach as we are taught" is not without some foundation. If preservice elementary school teachers find science is an exciting exploration of the natural world, and if they have opportunities to interact with that world, ask questions of nature, and search for order, they will be better prepared to present science in the same manner. In a report from the panel on Chemistry for Citizens, it is recommended that

1. Science courses included in the training of elementary school teachers should emphasize both the methods and materials appropriate to the discovery or inquiry approach these teachers will use in the classroom.
2. In colleges and universities, experimentation should be encouraged toward the development of humanistic, in-depth science courses much less committed to complete coverage of chemistry than has been the case in the past. Courses should be developed that deal with the philosophical and ethical implications of science, as well as with its practical implications.[1]

As was suggested in the literature review, the goals of basic science content courses for non-majors might best be achieved through some form of individualized instruction. Postlehwait suggests that the limitations and restrictions usually imposed by the conventional approach must be discarded and primary attention given to the needs of the individual student.[2] Carl Rogers typifies current criticism of educational practices when he states:

---

[1]"Chemistry for Citizens: Report of Panel IV, International Conference on Education in Chemistry," Journal of Chemical Education, XLVIII, (January, 1971), p. 23.

[2]S. M. Postlehwait, et. al., An Integrated Experience Approach to Learning With Emphasis on Independant Study, (Minneapolis, 1964), p. 3.

> When we put together in one scheme such elements as a prescribed curriculum, similar assignments for all students, lecture as almost the only mode of instruction, standard tests by which all students are externally evaluated, and instructor-chosen grades as the measure of learning, then we can almost guarantee that meaningful learning will be at an absolute minimum.[1]

In his book, Freedom to Learn, Rogers provides several possible alternatives to the type of course described above.

The AAAS Commission on Science Education urges that instruction be individualized so that students can satisfy requirements in different ways or in different lengths of time.[2] The report of the Belmont Conference recommended the production of systems of individualized instructional materials for teacher education in science and mathematics.[3]

It was the purpose of this study to develop and evaluate an individualized physical science course for preservice elementary school teachers, consistent with the guidelines and standards of the AAAS Commission on Science Education report.[4]

Statement of the Problem

At the time this study was conceived, the science content courses offered to satisfy the natural science requirement of prospective elementary school teachers at Venango Campus, Clarion State College, included Basic Biological Science, Basic Earth Science, Basic Physical Science I:

---

[1]Carl Rogers, Freedom to Learn, (Columbus, Ohio, 1969), p. 5.

[2]Preservice Science Education, p. 39.

[3]Glenn H. Crumb, director, An Exploratory Project on Training Elementary Teachers in Mathematics and Science, Report of the Belmont Conference, (Emporia, Kansas, 1968), p. 108.

[4]Preservice Science Education, pp. 52-53.

Chemistry, and Basic Physical Science II: Physics and Astronomy.

Basic Physical Science I: Chemistry is a three credit, one semester, essentially non-laboratory course. It was required of elementary education majors, although not designed specifically for them.[1] It may be elected by non-science majors in secondary education and by students in curricula other than education. The college consented to offer a section of this course for elementary education majors on an experimental basis, in order that a more appropriate course might be designed for them.

This study was divided into two major phases. The aim of the first phase was to develop a course in Basic Physical Science: Chemistry which would be appropriate for preparing elementary school teachers. To this end, the course should provide the student with some background in science content, selected in accordance with the recommendations of the several national elementary curriculum improvement groups and the concerned commissions. It should foster positive attitudes toward science and competence in the processes of science. It should encourage the capacity for self-direction in the student by using an auto-tutorial type of individualized instruction.

The development phase included, not only the preparation and selection of instructional materials and management procedures for the course, but also the design and preparation of suitable instruments for evaluation and testing.

The second major phase of the study was an evaluation of the effectiveness of the course in attaining its stated goals, and an assessment of the course's feasibility and acceptability.

---

[1]As a result of a recent liberalization of the general education requirements, specific courses are no longer required of elementary majors. They now must have 15 credits in science and mathematics courses in addition to methods courses.

Objectives of the Study

A. For the course development phase, the objectives were:

1. to design an auto-instructional course to attain the following three goals:

   a. Attitudes Toward Science. The science experiences in this course should develop in the prospective elementary school teacher an appreciation for the historical and current significance of science to society, for the nature of scientific inquiry, and for the personal characteristics of scientists. This should lead to positive attitudes toward science and scientists which can facilitate improved teaching of science in the elementary school classroom.

   b. Processes of Scientific Inquiry. The science experiences in this course should develop the prospective elementary school teacher's competence in using processes of scientific inquiry.

   c. Science Content. The science experiences in this course should provide the prospective elementary school teacher with an adequate background for the chemical topics taught in the elementary school.

2. to prepare and select suitable instructional materials and management procedures for the course.

3. to design appropriate procedures and prepare or select instruments for evaluation and testing.

B. The objectives for the course evaluation phase were:

1. to evaluate the effectiveness of the course in attaining the stated goals (see A.1., above).

2. to ascertain the acceptability of the course to the students and the degree of their satisfaction with specific instructional materials.

3. to assess the feasibility and manageability of the auto-instructional course.

Hypotheses

For the course development phase of this study, no hypotheses were stated or tested. During the evaluation phase, the following

hypotheses, derived from the goals of the auto-instructional course, were tested:

1. The students in the auto-instructional course will show an improvement in their appreciation for the historical and current significance of science to society, for the nature of scientific inquiry, and for the personal characteristics of scientists.

2. After completing the auto-instructional course, the students will display a positive attitude toward science and scientists.

3. The students in the auto-instructional course will show an improvement in their competence in using processes of scientific inquiry.

4. After completing the auto-instructional course, the students will display an adequate knowledge of science content.

The instruments developed and selected to test these four hypotheses are described in Chapter III, and the actual tests of the hypotheses are presented in Chapter IV.

Procedure

In phase I, the auto-instructional physical science course was developed prior to and during the January-May 1972 semester. It was pilot-tested with one class section of elementary education majors during that semester. The class included all those students who were elementary education majors and who elected Basic Physical Science: Chemistry. The course materials and evaluation instruments were revised and improved during the period from June to August, 1972. A complete description of phase I is presented in Chapter III.

The evaluation phase (phase II) involved the administration of the revised course and evaluation instruments to one class section during the September-December 1972 semester. Again the class included all

those elementary majors who elected Basic Physical Science: Chemistry. Concurrently, the course's acceptability and feasibility were assessed. While it was recognized that the several course components (e. g., individualized instruction, investigatory laboratory experiences) may contribute differentially to the attainment of the course goals, no systematic attempt was made to evaluate the contribution of any single component. Prior studies have focused on the effectiveness of most of the course's components taken singly. It is the synthesis of the several components into a unified whole that was evaluated in this study. A full description of Phase II procedures constitutes Chapter IV.

CHAPTER III

DEVELOPMENT OF THE AUTO-INSTRUCTIONAL COURSE AND THE ASSESSMENT INSTRUMENTS

Introduction

The guidelines and standards of the AAAS Commission on Science Education served as the principal basis for the development of the auto-instructional (A-I) physical science course. The development followed as many of these guidelines and standards as it was possible to address in a single course and in the context in which the course is offered.

> Guideline I. Science for elementary teachers should be taught in the same style of open inquiry that is encouraged in elementary science programs. The student's science experiences should develop his ability to actively investigate natural phenomena and should result in his enthusiasm for and confidence in teaching science through inquiry to children.
>
> Guideline II. Science experiences of elementary teachers should develop in teachers an appreciation for the historical, philosophical, and current significance of science to society, and positive attitudes about science which result in a more objective approach to everyday problems, in improved teaching of science in their classrooms as well as increased interest in science-related activities.
>
> Guideline III. The science experiences for elementary teachers should develop competence in inquiry skills or processes of scientific inquiry.
>
> Guideline IV. The content of college science experiences for elementary teachers should be selected so that the topics studied by teachers provide, as a minimum, an adequate background for the topics taught in elementary schools.
>
> Guideline V. Science experiences should be selected

> so as to develop a capacity and disposition for continuous learning which the teacher should demonstrate by engaging in science activities which will provide new information and experiences capable of affecting existing attitudes, ideas, and teaching.
>
> Standard 4. Institutions which prepare teachers should make every effort to allow for individual differences among students by planning instruction so that students may progress at different rates and by giving credit in completing program requirements for learning that is acquired before entering college or that is acquired through informal experiences during college.
>
> Standard 5. The institution should (a) provide laboratory facilities which will accomodate student activities that range from predetermined exercises proposed by the professor to student-constructed experiments; (b) furnish science equipment and materials similar to those in elementary schools; and (c) provide reference books suitable for use in a school setting.[1]

On the basis of these guidelines, it was determined that the course would contain the following elements: individualized instruction, investigatory laboratory experiences, an open inquiry style, and a multimedia approach. The individualization aspect included both the opportunity for the student to work on the materials at his own convenience and pace, and the opportunity to choose alternate and optional instructional materials.

The science content was determined after consulting the topics suggested for such a course by the AAAS Commission on Science Education.[2] The topics were further limited by the restrictions imposed by the college--a three credit, one semester, chemistry course. The unit and lesson topics developed for phase I are found in Table 1.

The investigatory experiences which are included in the individual lessons were chosen to develop the student's ability to use

---

[1] Preservice Science Education, pp. 52-53.

[2] Ibid., pp. 18-20.

TABLE 1

UNIT AND LESSON TOPICS: PHASE I

Unit I		The Composition and Structure of Matter: Elements and Atomism
Lesson	1	What is Science?
	2	Discovery of the Elements
	3	Lavoisier's New Chemistry: The Chemistry of Oxygen
	4	John Dalton and the Atomic Theory
Unit II		The Composition and Structure of Matter: Molecules and the Kinetic-Molecular Theory
Lesson	5	The Molecular Controversy: Avogadro's Theory
	6	The Kinetic-Molecular Theory
	7	The Mole
Unit III		The Electronic Structure of Matter and Chemical Bonding
Lesson	8	The Bohr Atom
	9	The Quantum Mechanical (Wave Model) Atom
	10	Bonding Forces in Matter
Unit IV		Carbon Chemistry
Lesson	11	An Introduction to Organic Chemistry
	12	Giant Molecules
	13	The Detergent Dilemma

processes of scientific inquiry. The format for specifying inquiry skills to be included was the student behavior categories as developed by Klopfer and presented in the Handbook on Formative and Summative Evaluation of Student Learning.[1] The specific behavior categories to be developed in the A-I course were determined after a consideration of the restrictions imposed by the course content, the suggestions of the AAAS Commission on Science Education,[2] and consultation with experts.

---

[1]Leopold E. Klopfer, "Evaluation of Learning in Science," in Handbook on Formative and Summative Evaluation of Student Learning by Benjamin S. Bloom, J. Thomas Hastings, and George F. Madaus (New York, 1971), pp. 561-575.

[2]Preservice Science Education, pp. 14-17.

TABLE 2

STUDENT BEHAVIOR CATEGORIES*

B. PROCESSES OF SCIENTIFIC INQUIRY I: OBSERVING AND MEASURING

- B.01 Observation of objects and phenomena
- B.03 Measurement of objects and changes
- B.04 Selection of appropriate measuring instruments
- B.05 Estimation of measurements and recognition of limits in accuracy of measurements

D. PROCESSES OF SCIENTIFIC INQUIRY III: INTERPRETING DATA AND FORMULATING GENERALIZATIONS

- D.01 Processing of experimental data
- D.03 Interpretation of experimental data and observations
- D.05 Evaluation of hypothesis under test in the light of the experimental data obtained

E. PROCESSES OF SCIENTIFIC INQUIRY IV: BUILDING, TESTING, AND REVISING A THEORETICAL MODEL

- E.01 Recognition of need for a theoretical model to relate different phenomena and empirical laws or principles
- E.03 Specification of phenomena and principles that are satisfied or explained by a theoretical model
- E.05 Interpretation and evaluation of the results of experiments to test a theoretical model

*Coding of categories is based on Klopfer, loc. cit.

Development of the Auto-Instructional Lessons

Each of the lessons in the course was designed to focus on one topic and, insofar as possible, to approximate the equivalent of one week's work in a traditional course. The principal instructional vehicle selected was the auto-instructional lesson guide (hereafter referred to as ALG).[1] These ALG's vary in content from lesson to lesson, but all include instructional objectives, core and optional activities,

[1] See appendix A for examples of ALG's.

and written exercises. Most contain suggested procedures, laboratory activities, short readings, and review sheets.

The instructional objectives are explicit statements of competencies the student is expected to possess following the completion of the lesson. The core activities include all those activities which are specifically directed toward the student's attainment of the competencies stated in the instructional objectives. These core-activities include readings from a basic text,[1] other readings from books and journals, film loops, and filmstrips. The optional activities include the same types of materials and media, but are designed for students who wish to explore some aspect of the topic in greater depth, for students who wish to pursue alternate pathways, and for students who still have difficulties after completing the core materials. The questions included with the ALG, as well as selected questions from the text, provide the student with opportunities to test his performance on competencies prior to taking the unit test.

No attempt was made to structure all of the lessons in the same manner. Some lessons make use of many outside readings, while others are virtually self-contained.[2] Some lessons make extensive use of audio-visual aids, while others contain many laboratory exercises. The overriding consideration in selecting lesson materials was to choose the best available materials for attaining the stated competencies. The already available materials were supplemented, when it seemed advantageous,

---

[1]William F. Kieffer, Chemistry: A Cultural Approach, (New York, 1971).

[2]See lesson 6, included in Appendix A, for an example.

with materials prepared especially for a specific lesson.

To inform the student what an ALG is, and how to use it, a guide sheet ("Auto-Instructional Lesson Guides") was prepared. It also includes a rationale for the course and some general comments about the course. This guide sheet is included in Appendix A.

Management Techniques

Implementation of the A-I course required the development of new management techniques, some of which are applicable to individualized courses in general, while others were necessitated by the physical limitations of the facilities available at Venango Campus. The basic philosophy was that, while an individual could choose to work alone on most of the course materials, many students would benefit by working on some materials (e.g. laboratory exercises or film loops) in pairs or in small groups.[1] It was arbitrarily decided to have all students meet as a group once a week. The purpose of these meetings was to allow for questions on any particularly difficult topics, to allow for group discussion, and to provide a sense of belonging to a group. Had the formative evaluation indicated that this decision was inappropriate, then an adjustment would have been made. This was not the case, however, and the practice was retained for phase II.

It was deemed desirable to have a classroom-laboratory facility available for fairly large blocks of time. This not only gave the students a greater choice in determining when they would work on the lessons, but also enabled a fairly large number of students to be accomodated with

---

[1]For instruction given the students in this regard see Auto-Instructional Lesson Guides in Appendix A.

a minimum amount of laboratory and audio-visual materials. The necessity of sharing this facility with other classes was a limiting factor. A schedule was worked out that made the facility available for the students in the A-I course about sixteen hours each week. (See Table 3.) During these scheduled hours the instructor or a laboratory assistant was always available.

TABLE 3

WEEKLY TIME SCHEDULE FOR USE OF CLASSROOM-LABORATORY

Monday	1:00 - 5:00
Wednesday	1:00 - 5:00
Thursday	10:00 - 2:00
Friday	1:00 - 5:00

The equipment needed for the investigations, film loops, filmstrips, and the core readings were all available in the classroom-laboratory. While carrels for individual use of materials are employed in some circumstances, the multiple uses to which this room was subjected precluded their installation. This limitation was overcome in several ways. Film loop projectors were fitted with wide-angle lenses and used with desk-top viewers. A lenticular screen was installed for viewing filmstrips. This allowed for simultaneous viewing of these kinds of materials at one end of the room without darkening the room. An unexpected benefit resulted. Several students could view and discuss a particular filmstrip or loop simultaneously. The use of carrels would have severely limited this type of small group interaction. There were times when individuals and small groups were simultaneously viewing film loops and filmstrips, reading, and conducting investigations, all in various parts of the room and without noticeable interference.

Core and optional readings were usually available both in the classroom-laboratory and on overnight reserve in the library. The number of copies was dependent on the length of the reading and the estimated usage.

Student Feedback Instruments

The formative evaluation was a systematic evaluation carried out during the development and pilot-testing of the A-I course. It included collecting evidence about the appropriateness of instructional materials, tests, and management techniques. It served as a basis for the revisions which were made prior to phase II.

Each student was asked to complete a Student Log Sheet (see Appendix B) for each lesson. These log sheets required the student to report which of the activities were completed for each lesson and to list the approximate time he spent on the lesson.

A Student Response Sheet (see Appendix B) was completed for each lesson by one-half of the students in the class. A random selection process was used in determining the respondents, so that each student was asked to complete a response sheet for only one-half of the lessons in the course. This response sheet asked the student to rate the adequacy of the instructional objectives and the lesson materials.

A Course Appraisal (see Appendix B) was administered to all students in the class at the conclusion of the course. In addition to questions concerning instructional materials and management techniques, this form inquired about the student's reactions to individualized instruction.

Additional formative evaluation information came from an exam-

ination of the student responses from the Test On Understanding Science, the Processes of Scientific Inquiry Inventory, and the Science Content Test. These test instruments are described in a later section of this chapter and copies of them may be found in Appendix C.

Formative Evaluation Findings

The A-I course was pilot-tested with 33 students majoring in elementary education during phase I. The findings presented here are based on the results obtained from the various formative evaluation measures employed during that time.

Student Log Sheets

An examination of the Student Log Sheets revealed that some students reported spending as little as one hour on certain lessons, while the most time reported spent on any lesson was ten hours (Lessons 4, 8, and 10). When all 13 lessons were considered, the mean time per student was 4.1 hours. Table 4 presents the data for each lesson.

TABLE 4

TIME SPENT ON LESSONS
(Number of Students Reporting on each lesson = 21 to 28; mode = 27)

	Least Reported	Most Reported	Mean
Lesson 1	1 hour	6 hours	3.6 hours
2	1	9	4.0
3	2	8	5.0
4	3	10	4.6
5	1	6	3.2
6	2	6	3.5
7	1	8	3.7
8	2	10	4.4
9	1	7	4.1
10	2	10	4.7
11	2	8	4.2
12	1	7	4.2
13	2	8	4.0
Total			4.1

It was not always the same students who spent the most and the least time on each of the lessons. When mean times were computed for all lessons, it was found that 7.2 hours was the highest mean time spent by any one student, while 1.8 hours was the lowest mean time reported. As the Student Log Sheets made no provision for reporting time spent in studying for unit tests, all mean times reported could probably be increased by from one-half to one hour.

The A-I course carried three semester hours credit. Had it been given in the traditional manner, there would have been three 50 minute class sessions per week (2.5 hours), plus whatever time each student elected to spend outside the classroom. As each of the lessons in the A-I course was designed to approximate one week's work, the mean time of 4.1 hours is within bounds. Perhaps more important is the fact that each student determined the amount of time he would spend on each of the instructional materials in the lessons.

Student Response Sheet

Table 5 is a summary of the responses to the first four questions on the Student Response Sheet. Brief descriptors are included with each question for convenience; the complete questions may be found on the copy of the Student Response Sheet in Appendix B. Since the students only responded to the final four questions if they chose to do so, those questions are not summarized in the table.

From an examination of the first four questions, the most significant finding is that the majority of the students felt that the instructional objectives and the instructional materials were appropriate. There was no strong evidence that any particular lesson was in need of

TABLE 5

SUMMARY OF STUDENT RESPONSE SHEETS
(Given as Percentages of Students Responding; N = 10 to 17; mode = 16)

Instructional Objectives Appropriate					Difficulty of Material					
Lesson	Strongly Agree	Agree	Disagree	Strongly Disagree	Lesson	Far Too Difficult	Too Difficult	About Right	Too Easy	Far Too Easy
1	12%	88%	. .	. .	1	. .	. .	88%	12%	. .
2	13	87	. .	. .	2	. .	13	87	. .	. .
3	10	70	20	. .	3	. .	30	70	. .	. .
4	8	77	15	. .	4	. .	. .	100	. .	. .
5	11	67	22	. .	5	. .	22	78	. .	. .
6	. .	94	6	. .	6	. .	12	88	. .	. .
7	8	67	25	. .	7	. .	17	83	. .	. .
8	. .	100	. .	. .	8	. .	44	44	11	. .
9	17	58	25	. .	9	. .	8	92	. .	. .
10	. .	90	10	. .	10	. .	20	80	. .	. .
11	. .	90	10	. .	11	. .	20	80	. .	. .
12	13	80	7	. .	12	. .	20	80	. .	. .
13	11	89	. .	. .	13	. .	. .	100	. .	. .
Materials Appropriate					Materials Interesting?					
Lesson	Strongly Agree	Agree	Disagree	Strongly Disagree	Lesson	Very Interesting	Somewhat Interesting	Average	Somewhat Boring	Very Boring
1	6%	82%	6%	6%	1	6%	29%	47%	17%	. .
2	7	93	. .	. .	2	7	13	53	27	. .
3	10	80	10	. .	3	. .	50	40	10	. .
4	. .	85	15	. .	4	8	54	31	8	. .
5	11	67	22	. .	5	. .	44	33	11	11
6	. .	93	7	. .	6	6	35	47	6	6
7	8	83	8	. .	7	. .	42	42	8	8
8	. .	89	9	. .	8	11	33	44	11	. .
9	8	83	8	. .	9	. .	67	25	8	. .
10	10	60	30	. .	10	20	20	40	20	. .
11	. .	90	10	. .	11	. .	60	40	. .	. .
12	. .	87	13	. .	12	27	20	33	20	. .
13	33	56	11	. .	13	44	55	. .	. .	. .

major revision.

An examination of the responses to the remaining four questions on the Student Response Sheet provided further information as to how students felt about the instructional materials. The responses to the fifth question ("List any particularly interesting materials.") revealed that the laboratory investigations were the most interesting materials. The following items were voluntarily cited as interesting by at least three students for the several lessons:

Lesson	Materials
1	Lab Investigations (9 students)
2	Terminology Guide (3)
3	Lab Investigations (3)
4	Lab Investigations (3)
6	Lab Investigations (4)
8	Using the Spectroscope (5)
10	Crystal Growing (3)
12	Nylon Demonstration (6)

The sixth question (materials to omit) received a total of only four responses on all 13 lessons. The seventh question (materials needing improvement) and the final question (other suggestions) received only nine and eight scattered responses, respectively.

Course Appraisal

A summary of student responses to the Course Appraisal is shown in Table 6. The descriptors listed for each question in the table are for convenience; the complete questions may be found on the copy of the Course Appraisal in Appendix B. Each of the first six questions was answered on a scale of 5 = most favorable to 1 = least favorable.

A response of 4 or 5 to the first six questions was considered favorable; a response of 3 was considered neutral; a response of 1 or

2 was considered unfavorable. An inspection of Table 6 reveals that favorable responses were given by a majority of students to all questions except number 1 (45% favorable) and number 5 (47% favorable). Even so, when unfavorable responses are considered, question 1 had only 13% and question 5 only 22%.

TABLE 6

COURSE APPRAISAL: SUMMARY OF RESPONSES
(Given as Percentages of Students Responding)
(N = 32)

Question	5	4	3	2	1
1. Topics appropriate	6%	39%	42%	10%	3%
2. Instructional objectives	39	45	10	. .	6
3. Lesson materials appropriate	26	39	26	10	. .
4. Test items fair and representative	47	31	16	3	3
5. Learned more in individualized course	22	25	31	9	13
6. Meeting once a week appropriate	45	23	19	10	3

	Yes	No
7. Materials used to greater degree	65%	35%
8. Materials used to lesser degree or eliminated	52	48
9. Would you take this course over the conventional?	72	28
10. Should more individualized courses be offered?	74	26

Questions 7 and 8 are concerned with types of instructional materials which should be used to a greater or lesser degree. The "yes" or "no" response to these questions was not so important as the types of materials the respondent listed following the question. The materials suggested for greater usage (question 7) were:

laboratory investigations	8 respondents
readings with lesson guide	7
filmstrips	6
film loops and films	7
readings from journals	5

Materials suggested for lesser usage (question 8) were:

readings from text	4 respondents
film loops and films	4
laboratory investigations	3
readings from journals	3

It seems at first paradoxical that the same types of materials were suggested both for greater usage and for lesser usage. The only conclusion which appears to be warranted is that students differed in the type of instructional materials they found helpful.

The fact that 72% of the respondents would take the individualized course again (question 9) and 74% thought that more individualized courses should be offered (question 10), was a hearty endorsement for the individualized approach. Those students who chose to explain their response to question 9 gave the following reasons for preferring the individualized course:

work at own pace	4 respondents
learned more	3
more appropriate	3
more interesting	2
motivation	2
freedom of choice	1
liked instructional objectives	1

These responses include most of the advantages of individualized instruction cited by its proponents. The responses are particularly encouraging because they came as voluntary explanations following question 9, for which no responses were required or suggested.

In response to the type of courses which should be individualized (question 11), the General Education category was most frequently mentioned (10 respondents), followed by courses in major field (8), no

preference (4), and professional education courses (1). Suggestions for improving the course (question 12) were many and varied, but the only ones listed by more than one student were to require laboratory reports (4), check on students doing work (3), and include more readings with the lesson guides(2).

Other Formative Evaluation Findings

Additional information contributing to formative evaluation resulted from an examination of student responses to the Test On Understanding Science (TOUS), the Processes of Scientific Inquiry Inventory (POSII), and the Science Content Test (SCT). These three test instruments, which are described in a later section of this chapter, were used primarily for reasons other than formative evaluation, but their contributions to the formative evaluation are discussed here.

Several of the questions on the POSII dealt with testing and revising theories (see category E in Table 2). The results on these questions were generally poor, with only 18% of the students selecting the correct response in one case, and 21% of the students selecting the correct response in another. The implication was that this category was not satisfactorily treated in the A-I course.

Several questions on the SCT that involved solving problems using Avogadro's Law and the mole concept yielded unsatisfactory results. In one case only 45% of the students responded correctly. Since the SCT is a criterion-referenced test and the correct response rate was generally much higher, the implication was clear that these types of problems were not adequately treated.

One of the goals of the A-I course, stated earlier, was to develop

an appreciation for the historical and current significance of science to society, for the nature of scientific inquiry, and for the personal characteristics of scientists. To assess any change which might have occurred in this regard, the TOUS was administered as a pre-test and post-test during phase I. A t-test for correlated groups showed the TOUS pre to post-test gain was significant at the .005 level. This was considered as satisfactory evidence that no revisions in the A-I course were suggested by the TOUS results.

Formative Evaluation Summary

The formative evaluation indicated that the A-I course was satisfactorily achieving most of its stated goals. This being so, no major revisions were required, and there was time for a concentrated effort to make those few improvements and additions which seemed to be indicated.

Revisions and Additions

The poor showing on POSII questions relating to theories resulted in a decision to rewrite lesson 6. Originally a straightforward presentation of the Kinetic-Molecular Theory, lesson 6 made use of a text reading and a variety of core and optional materials. It was determined that lesson 6 would be rewritten as a self-contained investigation of two heat theories: the Caloric Fluid Theory and the Kinetic-Molecular Theory. The postulates of both theories were stated early in the lesson guide, and the student was then asked to carry out a series of laboratory investigations, each time questioning how adequate each theory was in interpreting and explaining the observations. The revised

version of lesson 6 is found in Appendix A.

Other revisions were less extensive. A poor showing on SCT items, plus a few suggestions on the Student Response Sheets, indicated a need for improvement in problem-solving instruction in lessons 5 and 7. Since there were already adequate numbers of problems included in these lessons, sample solved-problems of each type were made available in the classroom-laboratory. Readings accompanying the lesson guides for lessons 8 and 10 were improved, based on suggestions from the Student Response Sheets. Other minor revisions included adding film loops or filmstrips (lessons 6, 10, 12, and 13), improving instructional objectives, improving laboratory investigations, and adding journal readings. In the few short months since lesson 13 had been written, much had transpired in the detergent controversy. Accordingly, an addendum was added to lesson 13.

Enthusiastic response to lesson 13, plus a few suggestions from the Student Response Sheets and the Course Appraisals, indicated the premium students placed on relevant topics. From a list of several possible topics, three were finally selected for development as optional lessons. It was determined that these topics would be far less structured than the other lessons to allow the student maximum freedom in purusing a topic or topics of his choice. Copies of the three optional lessons are included in Appendix A.

The unit topics, lesson topics, and types of instructional materials employed in each lesson of the revised course are summarized in Table 7. It was this revised version of the course which was administered and evaluated during phase II of the study.

TABLE 7

UNIT TOPICS, LESSON TOPICS, AND TYPES OF INSTRUCTIONAL MATERIALS EMPLOYED

	Topics	Readings from Text	Readings: Books and Journals	Readings with Lesson Guides	Terminology Guides	Written Exercises	Laboratory Investigations	Filmstrips	Films and Film Loops
Unit I	The Composition and Structure of Matter: Elements and Atomism								
Lesson 1	What is Science?	x	x		x	x	x		x
2	Discovery of the Elements	x	x		x	x	x	x	x
3	Lavoisier's New Chemistry: The Chemistry of Oxygen	x	x			x	x		
4	John Dalton and the Atomic Theory	x	x	x		x	x	x	
Unit II	The Composition and Structure of Matter: Molecules and the Kinetic-Molecular Theory								
Lesson 5	The Molecular Controversy: Avogadro's Theory	x	x	x		x			x
6	Heat: Fluid or Motion?	x	x	x		x	x	x	x
7	The Mole	x	x		x	x	x	x	
Unit III	The Electronic Structure of Matter and Chemical Bonding								
Lesson 8	The Bohr Atom	x	x	x		x	x	x	x
9	The Quantum Mechanical (Wave Model) Atom	x	x	x		x	x		x
10	Bonding Forces in Matter	x	x	x		x	x	x	x
Unit IV	Carbon Chemistry								
Lesson 11	An Introduction to Organic Chemistry		x	x		x	x		
12	Giant Molecules	x	x			x	x		x
13	The Detergent Dilemma	x	x	x		x	x	x	
	Optional Lessons: Science and Society								
	The Chemicals in Our Foods		x			x	x	x	
	The Pesticide Dilemma		x			x	x		
	The Drug Hang-Up		x			x	x		

The Test Instruments

Although the test instruments described in this section were used primarily in the evaluation of the A-I course (phase II), their selection or development was part of phase I. Three of the test instruments also made some contribution to formative evaluation, as was noted previously. Copies of the final versions of all the test instruments used in phase II are included in Appendix C.

Test On Understanding Science

The Test On Understanding Science (TOUS), form W is a published instrument that was judged to be appropriate for testing the first hypothesis (see Chapter II), and it was selected for this purpose. As stated in the accompanying manual for the test, TOUS measures understanding in three areas: the scientific enterprise, scientists, and the methods and aims of science. Appreciation of these three areas is listed in Chapter II as one of the goals of the A-I course.

The TOUS has been widely used in research studies. Cooley and Klopfer report its reliability, using the Kuder-Richardson Formula 20, as .76. The standard error of measurement is 3.49. The manual available with the TOUS gives a discussion of item analysis, validity, and norms. In this study, the TOUS was administered as a pre-test and post-test to all students in the class, both during phase I and phase II.

Survey of Attitudes and Opinions on Science and Scientists

To test the second hypothesis concerning attitudes toward science, the Survey of Attitudes and Opinions on Science and Scientists

(SAOSS), form CG_V, was developed by the author in collaboration with Leo Klopfer and Audrey Champagne at the Learning Research and Development Center, University of Pittsburgh. The areas considered in developing items for the SAOSS were:

Area I Role of Science in the Culture and Society
Area II Support of Science as an Enterprise in the Nation
Area III Scientists as People
Area IV Personal Involvement with Science

Each item on the SAOSS consists of a pair of dichotomous statements (labeled A and B) reflecting attitudes towards science and scientists. The respondent considers statements A and B together, and he has a choice of five responses. For each item, he may circle on the answer sheet a capital A or B to indicate a strong preference for one of the statements, he may circle a small a or b to indicate a moderate preference, or he may indicate no preference.

Content validity was established by submitting the 36 original items to a panel of ten judges. Each judge was asked to choose the statement in each pair which reflected a positive attitude toward science and scientists. Thirty-one items survived the process. The items were then randomized so that either A or B might reflect the positive attitude for any given pair. Of the 31 items in the test, the number assigned to each area was: Area I - 7, Area II - 5, Area III - 9, and Area IV - 10.

The reliability of the total test was determined using the Kuder-Richardson general formula as presented by Ebel.[1] Based on data from 28 students in phase II, the reliability was found to be .78.

The SAOSS was not available for use during phase I. It was ad-

---

[1]Robert L. Ebel, Measuring Educational Achievement, (Englewood Cliffs, N.J., 1965), pp. 328-329.

ministered at the conclusion of phase II.

Processes of Scientific Inquiry Inventory

The third hypothesis concerning inquiry skills was tested using the Processes of Scientific Inquiry Inventory (POSII). The items for the inventory were constructed to assess the inquiry skills included in the several student behavior categories listed in Table 2.

Content validity was established by submitting the items to five independent judges to determine that the items fairly represented the appropriate inquiry skills. Thirty-three items survived this process. The reliability of the test, as determined with 28 students in phase II, was .52 (Kuder-Richardson Formula 20).[1] This would probably be considered low if decisions about individuals were to be based on the test results, but is quite adequate for group decisions.[2]

The POSII was administered as a post-test in phase I. At that time it was still in the development process and consisted of 40 items. The revised instrument was given as a pre-test and post-test to all 28 students in phase II.

Science Content Test

The Science Content Test (SCT) consists of the four unit tests. Each item was designed to test a specific competency as stated in the instructional objectives of the individual lessons.[3] Most of the com-

---

[1] Ibid., pp. 318-320.

[2] Frederick B. Davis, Educational Measurements and their Interpretation, (Belmont, California, 1964), p. 24.

[3] See Appendix A for the instructional objectives from all thirteen lessons.

petencies from the individual lessons are represented by at least one item. In a few cases inclusion of an item for every instructional objective would have resulted in an excessive number of discussion questions. The assignments of items to instructional objectives on the final version of the SCT is shown in Appendix D. The SCT served to test hypothesis four and was the primary means of determining an individual's grade in the course.

The content validity of the SCT was established by a panel of five judges. They were asked to judge the appropriateness of individual items to test for the competencies stated in the corresponding instructional objectives. They also offered suggestions for improving items. The modified items were again submitted to the judges. Since this was a criterion-referenced instrument, no attempt was made to determine a reliability coefficient. According to Popham and Husek, existing indices of internal consistency are inappropriate for use with criterion-referenced tests, and it is not clear what should replace them.[1]

The four parts (unit tests) of a preliminary version of the SCT were administered at the appropriate times during phase I. Revisions were necessitated prior to phase II as a result of revisions in individual lessons and the instructional objectives. The four parts of the revised SCT were administered at appropriate times during phase II.

---

[1]W. James Popham and T. R. Husek, "Implications of Criterion-Referenced Measurement," Journal of Educational Measurement, VI (1969), p. 5.

CHAPTER IV

EVALUATION OF THE REVISED AUTO-INSTRUCTIONAL COURSE

Introduction

Phase I of the study, which included the development and revision of the auto-instructional course, was described in Chapter III. During the evaluation phase of the study (phase II), the revised course was administered to a class of 28 freshmen at Venango Campus during the September-December 1972 semester. This constituted all those elementary education majors who elected to enroll in Basic Physical Science: Chemistry during that semester.

The description of phase II, which follows, includes

1. an evaluation of the effectiveness of the course in attaining the stated goals.
2. an evaluation of the acceptability of the course to the students.
3. an assessment of the feasibility and manageability of the course.

Effectiveness of the Auto-Instructional Course

The three goals stated for the A-I course in Chapter II served as the basis for the evaluation of the effectiveness of the course. To facilitate the evaluation, these course goals were translated into the four hypotheses, which were also stated in Chapter II.

Appreciation for Science

The first hypothesis, as stated in Chapter II, was

> 1. The students in the auto-instructional course will show an improvement in their appreciation for the historical and current significance of science to society, for the nature of scientific inquiry, and for the personal characteristics of scientists.

Since its expressed purpose is well matched with the statement of the hypothesis, the Test On Understanding Science (TOUS) was selected to test the hypothesis. Stated in null form:

> H_o: There will be no significant difference in pre-test and post-test scores on the Test On Understanding Science, form W.

The pre-test was administered on 1 September 1972, during the first week of the semester. The post-test was administered on 13 December 1972. A t-test for correlated groups was computed.[1] The result, shown in Table 8, indicates a significant difference at the .01 level between TOUS pre- and post-test means. Hence, it was possible to reject the null hypothesis and conclude that the students showed an improvement in those areas measured by the TOUS.

While the analysis of TOUS means yielded valuable information about the overall performance of the students in the course, it did not reveal specific areas of strength and weakness of the A-I course in imparting appreciation for science. In order to do this, an item analysis technique was applied using a chi-square test of change, as described by McNemar and used by Klopfer and McCann.[2] For each item,

---

[1] W. James Popham, Educational Statistics: Use and Interpretation, (New York, 1967), pp. 152-153.

[2] Quinn McNemar, Psychological Statistics, (New York, 1962), pp. 224-227; Leopold E. Klopfer and Donald C. McCann, "Evaluation in Unified Science: Measuring the Effectiveness of the Natural Science Course at the University of Chicago High School," Science Education, LIII (March, 1969), pp. 157-163.

TABLE 8

COMPARISON OF PRE-TEST AND POST-TEST SCORES ON TOUS (N = 28)

	Mean	Standard Deviation	Test of Difference between Means for Correlated Groups	
Pre-test	32.29	5.19		
Post-test	35.64	6.79	t = 2.86	$p < .01$
Change	+3.35			

the frequencies of right and wrong responses on the pre-test and post-test were arranged in a fourfold contingency table. The value of chi-square was computed to measure the significance of the change in responses to each item. As seen in Table 9, there were significant improvements in responses on nine items. There were no significant changes from right to wrong answers.

Before making any judgements based on these chi-square results, two factors were considered. First, if a high percentage of students select the correct answer on the pre-test, there are few students who could register a change from wrong to right answers as a result of the course. In this event, even though most or all of the students who initially had the wrong response shifted to the right response, their numbers would be too small to yield a significant chi-square value. An interpretation that such items represent a weakness in the course is not justified. In order to avoid such an error, no item with a low chi-square value was considered to indicate a weakness when over 70 percent of the pre-test responses were correct. Seventeen such items

TABLE 9

CHI SQUARE VALUES FOR TOUS ITEMS
(Using McNemar's Test of Pre- to Post-Test Change)

Item		Item		Item		Item	
1	1.29°	16	1.00	31	.00°	46	6.40*
2	.20°	17	1.80°	32	1.29	47	.20
3	.67°	18	8.00**	33	.00	48	1.29
4	1.80°	19	.09	34	3.27	49	.69
5	.20°	20	.00	35	.67	50	.67
6	1.80	21	4.76*	36	.11°	51	1.33°
7	.82	22	.50	37	.25	52	.11
8	.40°	23	1.33	38	1.00°	53	.33°
9	.14°	24	.00°	39	.08	54	4.50*
10	.50	25	5.40*	40	.67	55	2.27
11	4.50*	26	.11	41	5.33*	56	1.00
12	1.33	27	3.00	42	.11	57	1.14°
13	.07°	28	6.00*	43	7.00**	58	.00
14	.40°	29	.29	44	1.29	59	.40
15	.50	30	1.80	45	.00	60	.69

*Significant at .05 level.

**Significant at .01 level.

°Dropped as indication of weakness since over 70% of responses on the pre-test were correct.

were identified.

The second factor which must be considered in interpreting chi-square values is a consideration of those students who made incorrect responses on both pre- and post-tests. If their number is high, indicating a difficult item, it is possible to have a statistically significant change when only a few students have selected the right response on the post-test. To avoid interpreting every significant pre- to post-test improvement as evidence of effectiveness of the A-I course, an item was not used for this purpose if less than 30 percent of the students answered it correctly on the post-test. No such items were found.

To interpret the chi-square values for strengths and weaknesses of the A-I course, the items were scrutinized by areas. The authors of the TOUS identified understandings about the scientific enterprise, understandings about scientists, and understandings about the methods and aims of science as the three areas the TOUS measures. An examination of Table 10 indicates that the methods and aims of science is the area most satisfactorily treated by the A-I course.

TABLE 10

NUMBER OF TOUS ITEMS WITH SIGNIFICANT IMPROVEMENT
(As Indicated by Chi-Square Values)

Areas	Number of Items			
	Total	Adjusted[a]	Significant	Percent[b]
Scientific Enterprise	18	13	2	15%
Scientists	18	11	2	18
Methods and Aims of Science	24	19	5	26

[a]Total items minus those answered correctly by over 70% of the students on the pre-test.

[b]The items on which a significant improvement was shown, as a percentage of the adjusted total.

Attitude Toward Science and Scientists

The second hypothesis, as stated in Chapter II, was

> 2. After completing the auto-instructional course, the students will display a positive attitude toward science and scientists.

The Survey of Attitudes and Opinions on Science and Scientists (SAOSS) was expressly developed to assess this hypothesis.[1]

[1]See Chapter III for a description of the development of the SAOSS.

The SAOSS was administered on 20 December 1972. Responses were scored by assigning a value of one if the student selected the least favorable response, and ranging up to five if he selected the most favorable response. The item mean scores shown in Table 11 were computed for each of the scales and the total SAOSS by dividing the group mean score for a given category by the number of items in the category. Thus an item mean score greater than three was interpreted as a positive (favorable) attitude toward science and scientists. An item mean score less than three was interpreted as an unfavorable attitude.

TABLE 11

GROUP MEAN SCORES ON THE SAOSS
N = 28

Scale		Mean Score	Standard Deviation	No. of Items	Item Mean
I.	Role of Science	28.92	3.60	7	4.13
II.	Support of Science	19.71	2.33	5	3.94
III.	Scientists as People	37.46	5.29	9	4.16
IV.	Personal Involvement	33.61	8.40	10	3.36
Total		119.70	13.14	31	3.86

The item mean score for the SAOSS was 3.86. Thus the decision was to accept hypothesis 2 and conclude that the students in the A-I class displayed a favorable attitude toward science and scientists.

Processes of Scientific Inquiry

The third hypothesis, as stated in Chapter II, was

3. The students in the auto-instructional course will show an improvement in their competence in using processes of

scientific inquiry.

The Processes of Scientific Inquiry Inventory (POSII) was developed expressly to assess this hypothesis.[1] Stated in null form:

> H_0: There will be no significant difference in pre-test and post-test scores on the Processes of Scientific Inquiry Inventory.

The pre-test was administered on 6 September 1972 and the post-test on 11 December 1972. A t-test for correlated groups was computed. The result, shown in Table 12, indicates a significant difference at the .001 level between POSII pre- and post-test means.

TABLE 12

COMPARISON OF PRE-TEST AND POST-TEST SCORES ON POSII
(N = 28, k = 33)

	Mean	Standard Deviation	Test of Difference between Means for Correlated Groups	
Pre-test	15.04	3.46		
Post-test	18.07	3.62	t = 5.42	$p < .001$
Change	+3.03			

The decision was to reject the null hypothesis and conclude that the students showed an improvement in their ability to use processes of scientific inquiry.

In order to identify areas of strength and weakness in the A-I course, the same item analysis technique was applied to the results of the POSII as was described earlier for the TOUS. As seen in Table

[1]Refer to Chapter III for a description of the development of the POSII.

13 there were significant improvements made in nine items. There were no significant changes from right to wrong answers.

TABLE 13

CHI SQUARE VALUES FOR POSII ITEMS
(Using McNemar's Test of Pre- to Post-Test Change)

Item		Item		Item	
1	7.37**	12	3.60^{o}	23	.11
2	.67^{o}	13	1.80	24	.60
3	.67^{o}	14	1.00	25	4.45*
4	6.40*	15	.00	26	1.80
5	4.57*	16	.82^{o}	27	.60
6	.40	17	.11^{o}	28	.09
7	12.25**	18	3.00	29	3.00
8	10.00**	19	1.60	30	.09
9	.00	20	2.67^{o}	31	4.50*
10	.00	21	.07	32	8.07**
11	.33^{o}	22	.33	33	.67

*Significant at .05 level.

**Significant at .01 level.

^{o}Dropped as indication of weakness since over 70% of the responses on the pre-test were correct.

To indicate strengths and weaknesses in the A-I course, the items were scrutinized by areas. Table 14 lists the significant items according to the Student Behavior Category they represent. An examination of Table 14 indicates that the A-I course was most successful in the area of observing and measuring and the subcategories included thereunder.

While the initial reaction to the results in the category concerning building, testing, and revising a theoretical model is disconcerting, it should be emphasized that the McNemar chi-square test yields results which point up relative, rather than absolute,

TABLE 14

NUMBER OF POSII ITEMS WITH
SIGNIFICANT IMPROVEMENT
(As Indicated by Chi-Square Values)

Category	Number of Items			
	Total	Adjusted[a]	Significant	Percent[b]
Observing and Measuring	12	10	6	60%
Interpreting Data and Formulating Generalizations	11	7	2	29
Building, Testing, and Revising a Theoretical Model	10	9	0	0

[a]Total items minus those answered correctly by over 70% of the students on the pre-test.

[b]The items on which a significant improvement was shown, as a percentage of the adjusted total.

strengths and weaknesses. The criteria applied for an item to be significant are harsh. In one case three students had responded correctly on the pre-test and incorrectly on the post-test, while nine students had changed from the incorrect response on the pre-test to the correct response on the post-test. Yet the chi-square value (3.00) still fell short of significance at the .05 level. While none of the ten questions in the third category showed significant improvement, improvement was shown on eight of the items. The best interpretation would be that the A-I course is doing a poorer job of imparting the inquiry skills represented by the third category, than in the other two categories.

Science Content

The fourth hypothesis, as stated in Chapter II, was

4. After completing the auto-instructional course, the students will display an adequate knowledge of science content.

The Science Content Test (SCT), consisting of four unit tests, was the instrument used to assess this hypothesis.[1] Each unit test was administered at the conclusion of the related unit. It had been determined that a score of sixty percent was the minimum score which would indicate an adequate knowledge of science content. An inspection of Table 15 reveals that all students in the A-I class exceeded the minimum criterion score.

TABLE 15

DISTRIBUTION OF SCORES ON THE SCT

Percentage Range	Number of Students	Percent
90 - 100	7	25.0
80 - 89	13	46.4
70 - 79	1	3.6
60 - 69	7	25.0
0 - 59	. .	. .

The decision was to accept the fourth hypothesis.

Acceptability of the Course

The second objective for phase II was to ascertain the acceptability of the course to the students and the degree of their satisfaction with specific instructional materials. The principal instruments used to measure this objective were the Student Response Sheet and the Course Appraisal. Both instruments were used earlier in phase I and described in Chapter III.

An inspection of Table 16 reveals that an overwhelming majority of students in the A-I class responded favorably to lesson materials

---

[1]The SCT is included in Appendix C. The development of the SCT is described in Chapter III.

TABLE 16

SUMMARY OF STUDENT RESPONSE SHEETS: PHASE II
(Given as Percentages of Students Responding; N = 10 to 15; mode = 13)

1. Instructional Objectives Appropriate

Lesson	Strongly Agree	Agree	Disagree	Strongly Disagree
1	40%	60%	. .	. .
2	33	67	. .	. .
3	18	73	. .	9
4	17	75	8	. .
5	40	60	. .	. .
6	25	75	. .	. .
7	30	70	. .	. .
8	17	83	. .	. .
9	23	77	. .	. .
10	20	80	. .	. .
11	27	73	. .	. .
12	8	92	. .	. .
13	8	92	. .	. .

2.a. Materials Appropriate

Lesson	Strongly Agree	Agree	Disagree	Strongly Disagree
1	13%	80%	7%	. .
2	7	93	. .	. .
3	9	73	18	. .
4	17	83	. .	. .
5	. .	90	10	. .
6	8	92	. .	. .
7	20	70	10	. .
8	8	75	17	. .
9	8	84	8	. .
10	10	80	10	. .
11	9	73	18	. .
12	8	84	8	. .
13	8	75	17	. .

2.b. Difficulty of Material

Lesson	Far Too Difficult	Too Difficult	About Right	Too Easy	Far Too Easy
1	. .	. .	80%	13%	7%
2	. .	33	67	. .	. .
3	. .	18	82	. .	. .
4	. .	8	92	. .	. .
5	. .	10	70	20	. .
6	. .	8	92	. .	. .
7	. .	20	80	. .	. .
8	. .	17	83	. .	. .
9	8	23	69	. .	. .
10	. .	10	80	10	. .
11	9	9	73	9	. .
12	. .	15	77	8	. .
13	8	. .	84	8	. .

2.c. Materials Interesting?

Lesson	Very Interesting	Somewhat Interesting	Average	Somewhat Boring	Very Boring
1	7%	40%	47%	7%	. .
2	7	13	73	7	. .
3	18	28	36	18	. .
4	8	34	50	8	. .
5	. .	30	60	10	. .
6	. .	42	50	8	. .
7	10	30	50	10	. .
8	8	25	67	. .	. .
9	8	23	54	15	. .
10	20	30	40	10	. .
11	9	36	27	27	. .
12	8	30	38	16	8
13	8	42	34	8	8

and instructional objectives on each of the thirteen lessons. The highest negative response found was the twenty-seven percent who found the instructional materials "somewhat boring" in lesson 11.

A summary of responses to the Course Appraisal is found in Table 17. If responses of two or one on the first six questions are considered as unfavorable, the highest unfavorable response would be on question five (32%). That sixty-eight percent of the students would take the individualized course over the conventional and seventy-one percent responded that more individualized courses should be offered, is an indication that the course is acceptable to a majority of the students.

In a more subjective manner, the students revealed their feelings about the course in a verbal fashion throughout phase I and phase II. While it is extremely difficult to report these revelations in any quantitative manner, a few thoughts were consistently expressed. Several students who had never had any particular interest in, or success in, a science course found that both were attainable. The stated instructional objectives were attractive to many. The freedom to choose from many types of materials was also frequently cited as attractive.

The only negative comment voiced with any frequency was that some students felt uncomfortable and unpressured to produce outside of a traditional classroom situation. At least two students indicated that, while the individualized approach was good for others, they were not self-motivated and needed prodding. This viewpoint could account for some of the unfavorable response to questions five, twelve, and thirteen in Table 17.

TABLE 17

SUMMARY OF RESPONSES ON THE COURSE APPRAISAL: PHASE II
(Given as Percentages of Students Responding; N = 28)

Question	5[a]	4	3	2	1
1. Topics appropriate	21%	39%	25%	11%	4%
2. Instructional objectives	36	21	36	7	. .
3. Lesson Materials	11	46	36	4	4
4. Test items fair and representative	36	36	21	4	4
5. Learned more in individualized course	36	18	14	14	18
6. Meeting once a week appropriate	50	25	18	7	. .
7. Optional topics better than core	8	27	46	8	11

	Yes	No
8. More optional topics; fewer core	22%	78%
12. Would you take this course over the conventional?	68	32
13. Should more individualized courses be offered?	71	29

[a]For questions one to seven, a 5 is the most favorable response; a 1 is the least favorable

Feasibility and Manageability of the Course

The third objective for phase II was to assess the feasibility and manageability of the auto-instructional course. In other words, would the implementation of an auto-instructional course of this type prove to be unwieldy and difficult to manage? The assessment of the course's feasibility and manageability was necessarily quite subjective.

As was indicated earlier, the students in the A-I class met as a group once a week, and they subsequently voiced approval of this

practice.[1] The classroom-laboratory was available for their use about sixteen hours per week. An undergraduate laboratory assistant was available during these hours. The principal duty of the laboratory assistant was to assist in locating and using instructional materials and equipment, but he was also able to assist with questions and problems on many occasions.

The instructor visited the classroom-laboratory periodically, and entered into small group discussions upon invitation, counseled with individual students, and answered questions regarding the laboratory investigations or other instructional materials. It is estimated that the instructor spent an average of approximately four hours per week in this manner. He was also available for individual conferences during scheduled office hours.

It is difficult to compare the amount of instructor time required by the A-I method with the amount of time spent in a more traditional approach. Inevitably, there is some extra time involvement whenever a new program is developed and implemented. It is the opinion of the author and others, that in subsequent administrations of the course the amount of time spent by the instructor of an A-I class would be approximately the same as the time spent administering a more traditional approach. It is felt, however, that a larger number of students could be efficiently served in the A-I class.

The most significant management problems which occurred were those which came as a result of the use of the classroom-laboratory by other classes. It was not always possible to leave apparatus and other

---

[1]For a more complete description of management practices, see the section on "Management Techniques" in Chapter III.

materials set up for long periods of time. The availability of a laboratory assistant to set up apparatus and move materials minimized these problems.

None of the other management procedures described in Chapter III was found to present any special problems. The Student Log Sheets served well to provide both the student and the instructor with a record of progress. The classroom-laboratory was found to be quite adequate. It would have been capable of handling during the allotted times much larger numbers of students than were actually enrolled in the course.

Summary

This chapter has described the evaluation phase of the study, namely an evaluation of the effectiveness of the A-I course, the acceptability of the course to the students, the feasibility and manageability of the course, and the findings with respect to each of these. Chapter V includes a summary of the findings and conclusions.

CHAPTER V

SUMMARY, CONCLUSIONS, AND DISCUSSION

The general intent of this investigation was to explore the possibility of developing a physical science (chemistry) course suitable for prospective elementary school teachers. Following a review of related literature and a statement of the problem, the investigation was divided into two major phases. The first phase involved the development, pilot-testing, and revision of an auto-instructional (A-I) physical science course. The second phase was an evaluation of the effectiveness of the A-I course.

In phase I, the A-I course was developed in accordance with guidelines issued by the Commission on Science Education of the American Association for the Advancement of Science. One class section of elementary education majors was used for the pilot testing and formative evaluation of the course during the January-May 1972 semester. The findings of the formative evaluation served as a basis for revisions in the course.

In phase II, the revised A-I course was administered to one class section of elementary education majors. The results of this administration were used to evaluate the effectiveness of the course, to ascertain the acceptability of the course to the students, and to assess the feasibility and manageability of the course.

Summary of Findings

The following findings were established on the basis of the data collected and analyzed in phase II.

1. There was a significant gain in mean scores between pre-test and post-test administrations of the Test On Understanding Science.
2. The students displayed a positive attitude towards science and scientists at the conclusion of the A-I course.
3. There was a significant gain in mean scores between pre-test and post-test administrations of the Processes of Scientific Inquiry Inventory.
4. All students in the A-I course exceeded the minimum score (60%) considered adequate on the Science Content Test.
5. A majority of students found the A-I course and the instructional materials acceptable, according to analyses of their responses to the Course Appraisal and Student Response Sheets.
6. The A-I course was both feasible and manageable. Its administration presented no major problems.

Conclusions

On the basis of the above findings, the following conclusions appear warranted.

1. The A-I course is an effective vehicle for developing an appreciation for the historical and current significance of science to society, for the nature of scientific inquiry,

and for the personal characteristics of scientists.

2. Students display a favorable attitude towards science and scientists after completing the A-I course.

3. The A-I course is an effective vehicle for developing competencies in using certain stated processes of scientific inquiry. It is relatively strong in developing the student's inquiry skills relating to observing and measuring. It adequately develops skills associated with data interpretation and formulating generalizations. It is relatively weak in developing skills associated with building, testing, and revising a theoretical model.

4. The A-I course is an effective vehicle for developing an adequate knowledge of science content.

5. The individualized approach is acceptable to a majority of students. It would be elected over a more traditional approach by a majority of those students who have been exposed to it.

6. A course using the individualized approach requires the development of unique management techniques, but is not significantly more difficult to administer than is a course using a more traditional approach.

Discussion

The original problem, as stated in Chapter II, was to develop a physical science (chemistry) course which would be appropriate for preparing elementary school teachers. Using the AAAS Commission on Science Education's Guidelines as a basis, an auto-instructional

individualized course was developed and evaluated. The general goals for developing the course were to provide the student with some science content background, to foster positive attitudes toward science and scientists, and to develop a competence in using processes of scientific inquiry. The preceding sections summarized the findings and the conclusions which were drawn following the course evaluation phase of the study.

The results of the course evaluation and, in particular, the feedback received from the students in the A-I class were very encouraging. In general, it could be said that the course was achieving its goals, the students were satisfied with the course, and the course was not difficult to administer or manage.

The A-I course will continue to be offered at Venango Campus. The task of revising and improving it will continue. Several possible changes which were suggested in the course of this study seem to be indicated at this point.

While readings from the text were satisfactory for some lessons, they were less than satisfactory for others. Moreover, less than half of the text was actually used, either for optional or core readings. Consideration must be given to finding a text more suited to the goals of the course or eliminating the use of a basic text.

Considering the value placed by the students on the inclusion of readings with the lesson guide, more of these readings should be developed. This could also serve to take up some of the slack, should the text be eliminated. It would seem wise to make use of the investigatory approach, best evidenced in lesson 6, in developing these readings.

Consideration will be given to combining or eliminating some of the existing lessons. An example would be lessons 8 and 9. It is probably not necessary for a prospective elementary school teacher to study both the Bohr model atom and the quantum mechanical atom in such detail. Any saving in time which would result could be profitably devoted to the existing optional lessons. Moreover the development of additional optional lessons should be considered.

Other changes which will be considered are less extensive. Improvements in the laboratory investigations, the addition of better optional materials (particularly filmstrips and film loops), and improvements in the management techniques are areas worthy of some attention.

Summary

In arriving at a judgement about the worth of the individualized A-I course, it should be remembered that most of the students completing the course will ultimately be elementary school teachers. Some, who have no particular interest in science, will be teaching science as well as several other subjects, while others will be science specialists. It is considered important that the student, in his preparation program, comes to realize that science is lively and interesting, that inquiry can be carried on in elementary school classrooms, that he can carry on investigations, that he can deal with and learn new science subject matter, and that science experiences are connected with social experiences. The individualized course would seem to be making a contribution toward accomplishing these ends.

BIBLIOGRAPHY

BIBLIOGRAPHY

Alyea, Hubert N. "The Function of General Chemistry." Journal of Chemical Education, XVIII (July, 1941), 309-310.

Arena, John E. "An Instrument for Individualized Instruction." Educational Leadership, XXVII (May, 1970), 784-787.

Bassett, Lewis G., Director, et. al. PSNS/An Approach to Physical Science. New York: Wiley and Sons, 1969.

Butzow, John W. and Pare, Roland. "Physical Science: A Multi-Media Facilitated Course." Journal of College Science Teaching, II (October, 1972), 29-32.

"Chemistry for Citizens: Report of Panel IV, International Conference on Education in Chemistry." Journal of Chemical Education, XLVIII (January, 1971), 22-26.

Crumb, Glenn H., Director. An Exploratory Project on Training Elementary Teachers in Mathematics and Science. Report of the Belmont Conference, Emporia, Kansas: Kansas State Teachers College Press, 1968.

Davis, Frederick B. Education Measurements and their Interpretation. Belmont, California: Wadsworth Publishing Company, Inc., 1964.

Dodson, B. C. A Survey of the Teaching Practices and Materials Used in Introductory College Chemistry. Office of Education Report, (August, 1968).

Ebel, Robert L. Measuring Educational Achievement. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1965.

Engel, Dorothy and Torgenson, K. J. "Individualized Science With Behavioral Objectives." The Science Teacher, XXXVII (November, 1970), 22-23.

Finley, Albert C. and Louderback, H. M. "A Different Kind of High School." The Science Teacher, XXXIV (October, 1967), 46-48.

Gallagher, James J. "A Comparison of Individualized and Group Instruction in Science." Journal of Research in Science Teaching, VII (1970), 253-263.

Goldsmith, Robert H. "Chemical Content of the Physical Science Course." Journal of Chemical Education, XLIV (October, 1967), 578-580.

Good, Carter V., ed. Dictionary of Education. New York: McGraw Hill, 1959.

Guidelines for Science and Mathematics in the Preparation Program of Elementary School Teachers. AAAS Miscellaneous Publication 63-7, 1963.

Haber-Schaim, Uri, et. al. College Introductory Physical Science. Englewood Cliffs, N. J.: Prentice-Hall, 1969.

Hiack, Paul S. "Laboratory Experiments in College Physical Science for Prospective Elementary School Teachers." Unpublished Doctoral Dissertation, Columbia University, 1966, Dissertation Abstracts, XXVII (1967), 2915A.

Hornig, Donald F. "New Problems Need New Answers," (a plenary address given to the International Conference on Education in Chemistry). Journal of Chemical Education, XLVIII (January, 1971), 30-32.

Jones, Haskell L. "The Development of Certain Aspects of Scientific Literacy in College Freshman Physical Science Students." Unpublished Doctoral Dissertation, Ohio State University, 1969, Dissertation Abstracts, XXX (1969), 1337A.

Kieffer, William F. "Chemistry, Curiosity, and Culture." Journal of Chemical Education, XLV (September, 1968), 550-555.

_____. Chemistry: A Cultural Approach. New York: Harper & Row, Publishers, 1971.

Klopfer, Leopold E. "Individualized Science in Focus." Unpublished paper presented to the Illinois State Academy of Science, April, 1971.

_____. "Evaluation of Learning in Science." Handbook on Formative and Summative Evaluation of Student Learning. by Bloom, Benjamin S.; Hastings, J. Thomas; and Madaus, George F. New York: McGraw-Hill, 1971.

_____, and McCann, Donald C. "Evaluation in Unified Science: Measuring the Effectiveness of the Natural Science Course at the University of Chicago High School." Science Education, LIII (March, 1969), 155-164.

Krockover, Gerald H. "On My Own: An Individualized Science Methods Course." Journal of College Science Teaching, I (December, 1971), 39.

Lunetta, Vincent N. and Odvard, Egil D. "Individualized Instruction in the Science Curriculum." School Science and Mathematics, LXXI (February, 1971), 121-128.

Mager, Robert F. Developing Attitude Toward Learning. Belmont, California: Fearon, 1968.

Mattheis, Floyd E. "A Study of the Effects of Two Different Approaches to Laboratory Experiences in College Science Courses for Prospective Elementary Teachers." Unpublished Doctoral Dissertation, University of North Carolina, 1962, Dissertation Abstracts, XXIII (1963), 4616.

McNemar, Quinn. Psychological Statistics. New York: Wiley and Sons, 1962.

Miller, Raymond E. "A Study of the Effects of Three Teaching Methods on the Learning of Selected Topics in a College Physical Science Course." Unpublished Doctoral Dissertation, Pennsylvania State University, 1962, Dissertation Abstracts, XXIII (1963), 2450.

Nazzaro, James R.; Todorov, Joao C.; and Nazzaro, Jean N. "Student Ability and Individualized Instruction." Journal of College Science Teaching, II (December, 1972), 29-30.

O'Toole, Raymond J. "A Review of Attempts to Individualize Elementary School Science." School Science and Mathematics, LXVIII (May, 1968), 385-390.

Parsegian, V. Lawrence, et. al. Introduction to Natural Science, Part One: The Physical Sciences. New York: Academic Press, 1968.

Perkins, Ronald J. "A Structured Independent-Study Course in Chemistry." The Science Teacher, XXXVII (November, 1970), 19-20.

Platt, John. "What We Must Do." Science, CLXVI (28 November 1969), 1115-1121.

Popham, W. James. Educational Statistics: Use and Interpretation. New York: Harper & Row, Publishers, 1967.

_____, and Husek, T. R. "Implications of Criterion-Referenced Measurement." Journal of Educational Measurement, VI (Spring, 1969), 1-9.

Postlehwait, S. N., et. al. An Integrated Experience Approach to Learning With Emphasis on Independent Study. Minneapolis: Burgess Publishing Co., 1964.

Preservice Science Education of Elementary School Teachers. (report of the AAAS Commission on Science Education), AAAS Miscellaneous Publication 70-5, 1970.

Puri, O. P., et. al. Concepts in Physical Science. Reading, Massachusetts: Addison-Wesley, 1970.

Ramsey, Irvin L. and Wiandt, Sandra L. "Individualizing Elementary Science." School Science and Mathematics, LXVII (May, 1967), 419-427.

Rasmussen, L. V. "Individualizing Science Education." Educational Technology, X (January, 1970), 53-56.

Rigden, John S. "An Individualized Approach to Introductory Physics." American Journal of Physics, XXXVIII (December, 1970), 1407-1412.

Robinson, Jack H. "Effects of Teaching With Science Articles." Science Education, XLVII (February, 1963), 73-83.

Rogers, Carl R. Freedom to Learn. Columbus, Ohio: Merrill Publishing Co., 1969.

Siemankowski, Francis T. "An Auto-Paced Teaching Process in Physical Science for Elementary Teacher Preparation: A Pilot Report." Journal of Research in Science Teaching, VI (1969), 150-156.

Smith, Charlie J. "A Comparative Study of Two Methods of Teaching of Physical Science to College Freshman With Disadvantaged Backgrounds." Unpublished Doctoral Dissertation, University of Mississippi, 1970, Dissertation Abstracts, XXXI (1970), 1152A.

Stekel, Frank D. "The Effects of Increasing the Student Involvement in a College Physical Science Laboratory Program." Unpublished Doctoral Dissertation, Indiana University, 1970, Dissertation Abstracts, XXXI (1971), 5880A.

Victor, Edward. "Why Are Our Elementary Teachers Reluctant to Teach Science?" Science Education, XLVI (March, 1962), 185-192.

Weaver, Allen D. "A Determination of Criteria for Selection of Laboratory Experiences Suitable for an Integrated Course in Physical Science Designed for the Education of Elementary School Teachers." Unpublished Doctoral Dissertation, New York University, 1954, Dissertation Abstracts, XV (1954), 238.

Williams, William W. "An Experimental Investigation of Individualized Instruction in the Teaching of Quantitative Physical Science." Unpublished Doctoral Dissertation, Duke University, 1969, Dissertation Abstracts, XXXI (1970), 312A.

Wolfson, Bernice J. "Pupil and Teacher Roles in Individualized Instruction." The Elementary School Journal, LXVIII (April, 1968), 357-366.

Wolke, Robert L. "Chemistry for the Non-Science Major." Journal of Chemical Education, XLVII (December, 1970), 788-793.

Zitelli, Patsy A. "An Evaluation of a Cooperative Teaching Method in Basic Physical Science as Required of Non-Science Majors." Science Education, LI (April, 1967), 295-298.

Cooley, W. W. and Klopfer, L. E. Test On Understanding Science, Form W. Princeton, N.J.: Educational Testing Service, 1961.

APPENDICES

APPENDIX A

SAMPLE INSTRUCTIONAL MATERIALS

Auto-Instructional Lesson Guides

Lesson 1. What is Science?

Lesson 6. Heat: Fluid or Motion?

Lesson 13. The Detergent Dilemma

Optional Lessons: Science and Society

Instructional Objectives

AUTO-INSTRUCTIONAL LESSON GUIDES

The auto-instructional lesson guide is a method for individualizing instruction. It doesn't teach you, but tells you where to get the information. Instead of working as a class, you will be working on your own. You may cover practically the same material that you would have in a group. This will depend in large part on you, your needs and your interests. Some of the benefits to you are as follows:

1. You will work at your own speed. Some students read faster than others. Some need to use different kinds of materials to best understand a given topic.

2. You will have great freedom to adapt the program to your own needs. At the end of an auto-instructional lesson you should have a thorough knowledge of the material included. You may have a fair knowledge of some of the concepts before you start. There is no reason for you to spend as much time on such topics as you would in a conventional course. A friend of yours may need to spend more time on the same topic. Still another student may need as much time on the topic, but prefer to use a different method to achieve competency.

3. You can work alone or with a group. While the course is individualized, you can still work with others in discussions, viewing audio-visual aids, and performing experiments. A combination of individual and group work may prove to be the best way to pursue a topic.

4. You can work when you want and as long as you want at a time. The classroom-laboratory will be available for considerable periods of time daily. (a schedule will be posted) Most of the materials you need will be found there.

5. Your instructor, or a lab assistant, will be available during all scheduled hours. Just because you are working individually doesn't mean your teacher is not available for help. You may wish to have small group discussions, with or without the instructor, to clarify a topic. You may wish to consult with the teacher individually on a difficult question, planning a lab experience, or planning and executing your program.

While there are many advantages to an individualized program, it is only fair to warn you that you must learn to accept responsibility. Nobody will be constantly checking to see that you are working. After completing a unit consisting of two or more lessons, your progress will be tested in some fashion. To assure success, you will need to check yourself to see that you are making progress.

RATIONALE FOR THE COURSE

This course is a basic physical science: chemistry course which has been designed for prospective elementary teachers. The emphasis in this course is not placed solely on chemical knowledge. It is recognized that equally important goals are developing competence in using processes of scientific inquiry and developing an understanding of the relationship of science to society. These have been identified by a national study as important skills for an elementary teacher. This course will attempt to spend as much time developing these latter skills as the former.

In addition to the benefits of individualized instruction mentioned on the first page, there is another bonus for the prospective elementary teacher. Many attempts at individualizing science instruction are being carried out in the nation's elementary schools. Every indication is that this trend will become more widespread. While there are many ways to individualize instruction, exposure to one type in this course should provide valuable first-hand experience. Keep in mind, however, that this is not meant to replace the methods course in the teaching of elementary science.

WHAT DOES A LESSON GUIDE INCLUDE?

Each auto-instructional lesson guide will contain most of the following:

Instructional Objectives
Core (Required) Activities
    Usually a basic textual reading, other readings, experiments audio-visual aids, etc.
Optional Activities
    Similar to the core activities, often allowing for greater depth of exploration, alternate pathways, etc.
Self-Evaluation Questions and Problems
    Both from the basic text and questions included on the guide sheets.
Vocabulary and Concept Guides

You are the one in the best position to determine what is the best procedure for you to follow, but you may find these suggestions helpful initially:

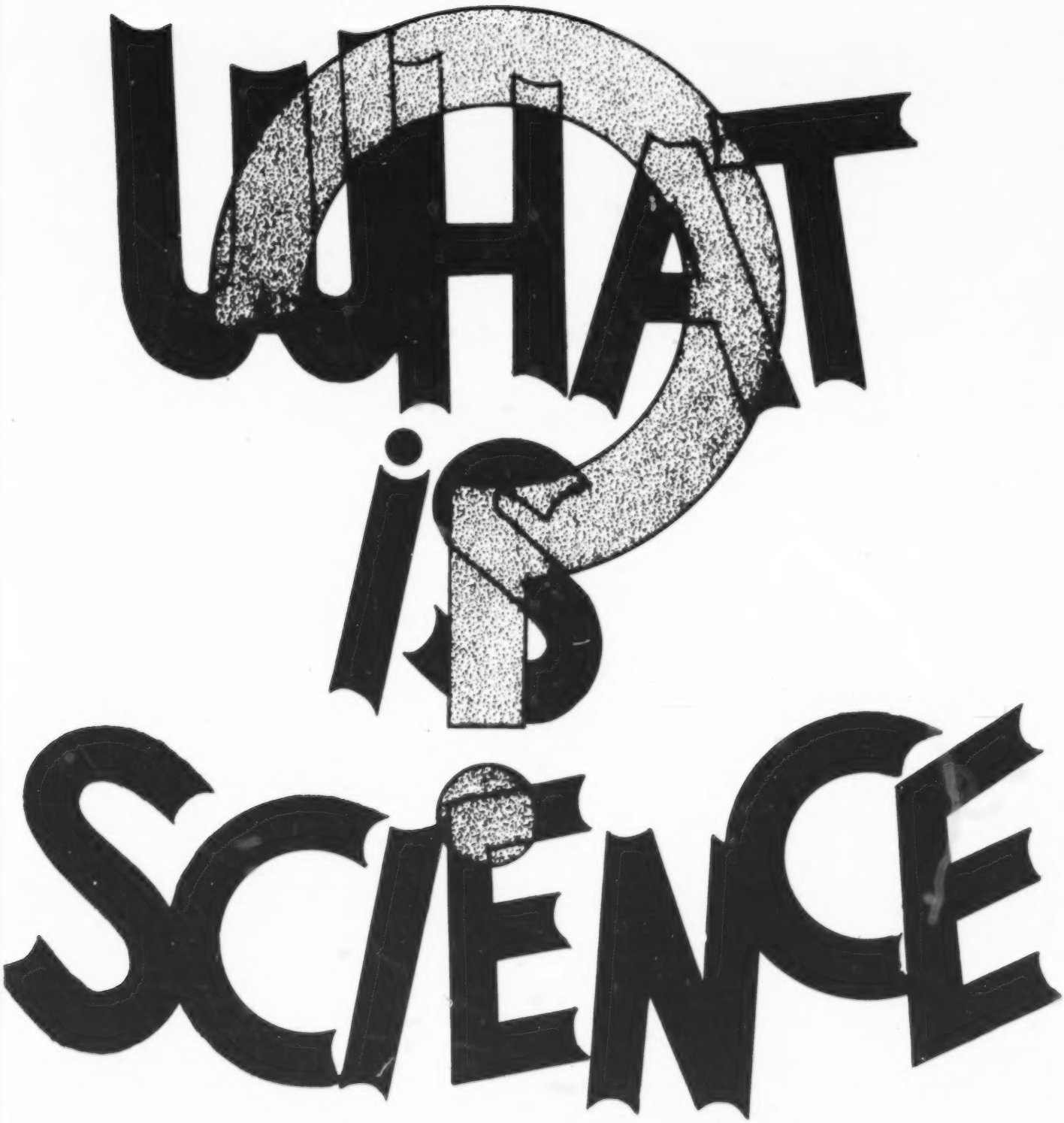
1. Read all of the instructional objectives in order to understand the scope of the study expected of you. By the time you have completed the lesson you are expected to have the competencies indicated.

2. Carry out the core activities suggested. The use of the word "core" is perhaps preferable to the term "required". While it is the opinion of the instructor that core materials are the most important, each student's situation is different. As you gain experience in using these lesson guides, you should become more proficient in deciding which materials are best for you. In any event, do not consider the labels "core" or "required" to be a mandate.

3. Each lesson will include suggestions for many optional activities. Each will have a brief description to guide you in your selection. Some are meant to be alternates for core activities, others are included for those having difficulties after using core materials, still others for those interested in investigating certain aspects of the topic. Your performance on the self-evaluation materials may serve as a useful guide in selecting optional materials.

GENERAL

Many of the readings, audio-visual aids, etc., will be available in the classroom-laboratory. In a few cases materials will be on library reserve. While most film strips and loops should be readily available, a few days notice is required to obtain movies. Most of the lab materials are available in the room. Consult the instructor or lab assistant for their location. Never attempt the lab activities without the instructor or lab assistant present. Forms will be available to keep a record of the activities you used in each lesson. Keep your copy and the instructors copy up-to-date.


WHAT
IS
SCIENCE

LESSON 1. WHAT IS SCIENCE?

Instructional Objectives This is not meant to be an exhaustive list, but rather a representational listing of competencies you should have following lesson 1. Some of these you may already have to some degree prior to completing the lesson. Following the completion of lesson 1 you should be able to:

A. Distinguish between observations and inferences.
B. Define scientific law, theory, and hypothesis.
C. Distinguish between laws and theories.
D. Explain or recognize an explanation of the relationship between a theory and a model.
E. Identify those human attributes a scientist should exhibit in his work.
F. Choose from among several examples, the one which best illustrates the usual outline of scientific method.
G. Formulate an argument for why "scientific method" as it has often been presented as a hard and fast procedure, is coming under attack.
H. Draw a distinction between science and technology.
I. Discuss the standards by which you believe we can determine how much of our national effort should go to basic science as opposed to technology.

Suggested Procedure

It is suggested that you first read the core readings. The laboratory activities may be performed at the conclusion of the readings or in the course of the readings, where this seems to be appropriate. For instance, you may want to carry out the activity on observations immediately after reading the account of observations on pp. 2-3 of the basic text. The instructor or laboratory assistant will be available during the scheduled hours to give assistance in locating materials, answering questions, etc. Following the required readings and laboratory activities you should attempt to answer the written exercises. The answers may then be consulted to see how you have fared.

After completion of the required activities, you may wish to choose one or more of the optional activities. Some of these activities are designed to strengthen concepts already developed, some are included primarily for those who may be having trouble comprehending the required material, and some offer supplementary readings and activities which may appeal

to different students. Consult the descriptions given to determine which of these activities would best serve you.

Core (required) Activities

A. Readings
   1. Kieffer, William F., Chemistry, A Cultural Approach, pp. 1-15. (basic text)
   2. Bronoski, J., The Common Sense of Science, pp. 1-17. (this section on "Science and Sensibility" gives, in simple narrative fashion, a rationale for considering the arts and science as noncontradictory contributors to culture)

B. Written Exercises
   1. Kieffer, William F., page 16, exercises 1, 2, 4, 6, 7, 8.
   2. Questions at the end of this lesson guide.

C. Laboratory Activities
   1.1. Observations: Burning a Match.
   1.2. Observations: Alka-Seltzer.
   1.3. Building a Mental Model: Black Box.

Optional Activities

A. Readings
   1. Johnson, R. H., and Grunwald, E., Atoms, Molecules and Chemical Change., pp. 1-9. This is briefer description of the basic concepts found in the required reading in the text. Suggested if you have difficulty with the written exercises.
   2. Hardwick, E. R., and Knobler, C. M., Man and Matter, pp. 1-3. A very brief discussion of what science is, including concise definitions of fact, law, theory and hypothesis.
   3. Hurley, T. H., "We Are All Scientists". A brief article found on pp. 12-18 of The New Treasury of Science, edited by Harlow Shapley. Some brief examples demonstrate that in our everyday experiences we all use those same mental attributes normally ascrubed to scientists.
   4. Conant, James B., Modern Science and Modern Man, pp. 3-30. This section of Conant's book gives an account of the relationship of science and technology in the twentieth century. It explores the consequences of government-imposed

secrecy on scientific pursuits. It shatters the myth that there is one hard and fast "scientific method". It is not necessary to read this entire selection to get the "flavor of the presentation".

B. Films

1. "Scientific Method", 12 minutes, color E.B.F. This film explains the steps of the scientific method, demonstrates the way problem solving is applied by scientists, and discusses the value of scientific thinking in dealing with everyday problems. It features the discovery of penicillin by Sir Alexander Fleming.

LABORATORY ACTIVITIES

1.1. Observations: Burning a Match

A. The purpose here is not to insult your intelligence, nor to establish a chemically correct explanation, but to illustrate that when you are confronted with an observation of some phenomenon, you should think about how it might be further studied in order to achieve some kind of satisfactory explanation. Strike an ordinary wooden table match and watch it burn. In your notebook make a list of as many details observed as possible. Can you list ten or more? Compare your list with one or more classmates. Did you miss anything? List some inferences you could make based on your observations.

B. Hold a glass plate or an empty glass beaker above a lighted match. Can you add anything to your list of observations? inferences?

C. Repeat the activities suggested above with other sources of flame such as a candle, gas burner, cigarette lighter, etc. Are your observations the same?

D. Can you suggest other variations which will allow additional observations regarding the flame. (such as the use of the glass plate in Part B)

E. What conditions did you control in this investigation? (were the windows open, etc.) Those conditions which may effect the outcome of an investigation are often called <u>variables</u> by scientists. Can you identify some of the variables of this investigation which may have affected the

results? Can you identify any variables which probably would not affect the results? (Would it matter if the investigation was done on Monday or Tuesday?)

1.2. Observations: Alka-Seltzer and Water

A. Drop an alka-seltzer tablet in a half glass (or medium beaker) of water. Again, as in the first investigation, make a list of observations. Compare your list with others.

B. What variations can you suggest to yield more observations of the phenomenon under investigation? For instance, if you believe you have evidence of a gas being released, what might you do to verify this? Check with the instructor or lab assistant before carrying out any procedure with questionable safety factors.

C. What conditions did you control in this experiment? List as many of these variables as you can. Can you check to see which of these variables have a significant affect on the results?

1.3. Building a Mental Model: Black Box

A. Examine each of the sealed boxes provided for this investigation. Without opening them, what might you do to build a mental model of the contents? Describe what might be in each of the boxes and reasons for your choices. The object is not to determine what is in the boxes, but rather to construct a model of what might be in the boxes. You may manipulate the boxes, use a magnet, or use any other procedure you wish short of opening the box or destroying it.

B. When a scientist has some system under investigation, where there are limitations as to the number of direct observations which can be made, he has a "black box". Is a scientist not as limited in his ability to "see" the parts of an atom as you were in not being able to see into the box?

C. Can you cite any similarities in your construction of a mental model and the development of scientific theories?

Questions: Lesson 1

1. Read the following cases and indicate in which of these cases scientific method (or a scientific way of thinking) has been used:

   a. On vacation in the mountains of Colorado, John notices that water seems to come to a boil faster than back home in Kansas. He suspects that it has something to do with the difference in altitude. He devises a method to check his suspicions by timing how long it takes a given quantity of water to come to a boil at various altitudes.

   b. A strange malady begins killing cattle in Clark County. Scientists, in searching for a cause, first notice that the afflicted animals all come from flat, low-lying regions of the county. They further discover that in all of these areas where the disease is prevalent, there are swamplands with stagnant water. Suspecting a mosquito-borne disease, they focus their attention on this aspect of the problem, devise methods for confirmation and elimination of the problem.

   c. Mary found that one of the four pies she had baked was not nicely browned on the bottom. She knew that she had used the same dough for each and had baked them the same length of time. On inspection she found that two of the pies were baked in the same type of glass pan, a third pie in an old, black-bottomed pan, and the fourth in a shiny, new tin pan. Suspecting that the shiny surface on the new pan reflected heat away from the crust, she heated the empty pan in the oven for a few hours to dull the shiny surface. Her next four pies all had nicely browned crusts.

2. Referring to questions 1.a., what scientific term could be applied to John's suspicion regarding altitude?

3. Can you suggest additional variables, other than the quantity of water, which John should have controlled? (refer to 1.a.)

4. Referring to question 1.b., if mosquitoes were brought under control, but the disease still prevailed, could the bodies of stagnant water be ruled out as a significant variable? why?

5. Again referring to 1.b., do you think it was a wise choice to focus the investigation on mosquitoes, at the expense of other possible explanations? why?

6. Do you believe that there is a basic difference in the type of intellect possessed by accomplished musicians, renowned painters, and research scientists? Give arguments to support your answer. (for help you may refer to the required reading by Bronoski)

7. Jonas Salk discovered a vaccine which has virtually eliminated polio. Would you cite this as an example of science or technology? Why?

8. Referring to the previous question , if most of the original volunteers to receive the vaccine contracted the disease and died, should Dr. Salk have been held responsible? Under what conditions?

9. Leonardo Da Vinci was known as a painter, sculptor, mathematician, and engineer in the Renaissance. Many other examples of men with achievements in the arts and the sciences can be found throughout history. Is this still true in the twentieth century? If you think this is no longer true, to what do you attribute the change?

TERMINOLOGY GUIDE SHEET: LESSON 1

Hypothesis - A tentative explanation based on the available experimental data. A conjecture or "educated guess". Sometimes hypotheses are stated or proposed for the explicit purpose of setting up an hypothesis testing situation or experiment.

Inference - A conclusion arrived at by reasoning from evidence. The act of passing from one proposition considered true to another proposition whose truth is believed to follow from the first.

Model - While the term, model, is sometimes used as a synonym for theory, it is more often used in a slightly different manner, A model is a visualization of structures and processes which cannot be directly seen, but which will help make a theory understandable. The mental image that we call a model, might be illustrated by an actual physical model or drawing.

Observation - An event or occurrence noted by one of the senses, sometimes with the aid of measuring instruments. (If we see a color change on mixing two solutions, this is an observation. If we conclude that a chemical change is taking place because of the observed color change, this would be an inference.)

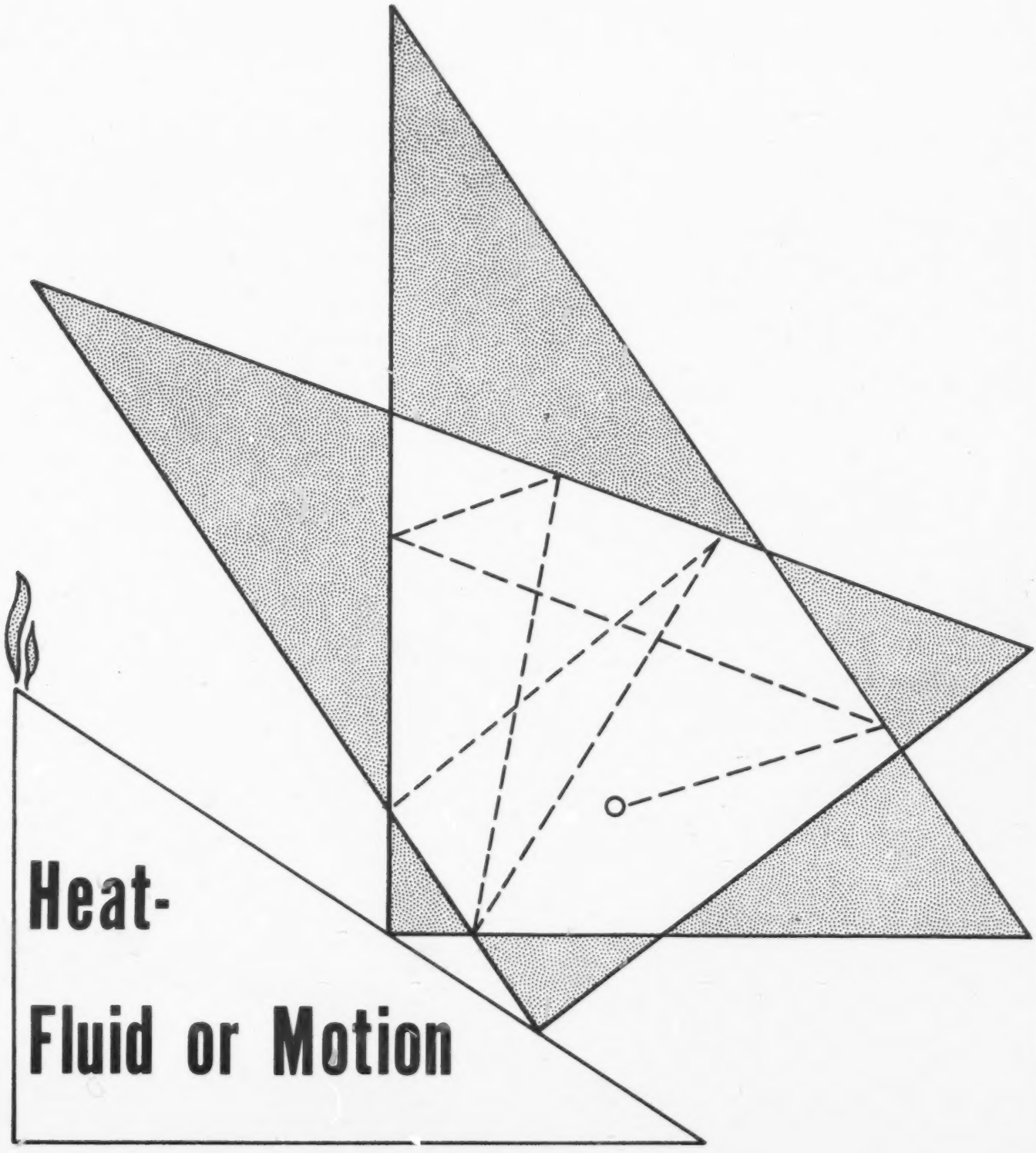
Science - A search or quest for knowledge. A human activity by which knowledge of natural events accumulates from a rational approach to problems.

Scientific Law - A series of facts based upon conclusive evidence and arranged in a precise statement. According to Kieffer a law is a "recipe" which nature appears to follow. Laws are useful in predicting what will occur in a given situation, but they do not explain or interpret.

Technology - The application of scientific knowledge to the solution of problems, especially in industry, commerce, and medicine.

Theory - A group of postulates or assumptions all relating to a single conceptual theme, for example, the atomic theory, the kinetic molecular theory, etc. The major functions served by a theory are to explain various phenomena in a particular area, to correlate or tie together these phenomena in a rational manner, and to suggest new problems for investigation.

Lesson 6



LESSON 6. Fluid or Motion?

Instructional Objectives Following the competion of this lesson you should be able to:

A. Evaluate the two heat theories presented on the basis of the available evidence, and determine if either one is more acceptable than the other.

B. Explain or interpret common phenomena (such as the increase of tire pressure following driving at highway speeds, the inflation of a balloon on adding gas, the odor of a factory across a city etc.) by using the appropriate postulates of either heat theory.

C. Cite or recognize those items of experimental evidence that may allow you to prefer one heat theory over the other.

D. Predict what will happen when one or more of the variables (volume, pressure, temperature) are changed in a given situation.

E. Explain how the postulates of the kinetic molecular theory can explain Boyles and Charles Laws.

F. Solve problems involving Boyles and Charles laws as illustrated by questions 12 and 13 following this lesson.

G. Solve problems involving heat and temperature as illustrated by questions 10 and 11 following this lesson.

Core Activities

A. Readings

1. Reading with this lesson guide, "Heat: Fluid or Motion?" The core and optional investigations are included in this reading at the appropriate places.

B. Questions

1. Questions included throughout core reading 1.
2. Questions following core reading 1.

C. Film Loops/Strips

1. Gas Diffusion Rates, 4 min. film loop Ealing. This is really an investigation of film. You will need pencil and paper to record data. Use after core reading 1.

D. Laboratory Activities

1. 6.1 Temperature and Heat
2. 6.2 Measuring Temperature
3. 6.4 Conservation of Heat
4. 6.5 Gases and Heat
5. 6.9 Kinetic Molecular Theory Demonstration (overhead projector) (will be scheduled)

Optional Activities

A. Readings

1. Roller, Duane, "The Early Development of the Concepts of Temperature and Heat", Harvard Case Histories in Experimental Science, Vol. I. pp 119-211.
   While this reading is lengthy, certain portions are referenced throughout core reading 1.
2. Jones, Mark M., et. al., Chemistry: A Brief Introduction, pp. 76-80. A concise supplement to core reading 1.
3. Johnson, R.H., and Ernest Gruwald, Atoms, Molecules and Chemical Change, pp. 76-87.
4. Kieffer, W. F., Chemistry, A Cultural Approach, pp. 108-117.

B. Programmed Material

1. Ford, Renee G., Kinetic-Molecular Theory of Gases. Parts A and B explain the theory and how it explains the gas laws. These parts would be a good exercise for those having difficulty with the core reading. Part C and D are not recommended. Part E is a good review of scientific laws and theories.

C. Film Loops/Strips

1. Molecular Motions in Condensed Phases, 4 min. film loop, Ealing.
2. Boyles Law, EBEC Filmstrip.
3. Charles Law, EBEC Filmstrip.

D. Laboratory Activities

1. 6.3 Change of State
2. 6.6 Odors
3. 6.7 Rate of Diffusion: Gases
4. 6.8 Rate of Diffusion: Liquids

Suggested Procedure

This lesson centers around the following reading. Contrary to your experience in other lessons, you will find both core and optional laboratory investigations and questions included at the appropriate places throughout the reading. It is suggested that you follow the reading as presented, answering the questions and conducting the investigations as they occur. While investigations 6.7 and 6.8 are listed as optional, you are to carry out at least one of them. Investigation 6.9 is a demonstration which will be scheduled for the group.

HEAT: FLUID OR MOTION?

INTRODUCTION

In this lesson you are asked to investigate two theories which may be used to interpret heat phenomena, the caloric fluid theory and the kinetic molecular theory. The purpose of this investigation is not to determine which theory is "right" or "wrong". From your earlier studies you should recall that no theory can be labelled "right" or "wrong". The major functions served by a theory are to explain various phenomena in a particular area, to correlate or tie together these phenomena in a rational manner, and to suggest new problems for investigation. A theory is a group of postulates or assumptions about a particular scientific area which collectively serve to accomplish these functions.

A major contribution to the advancement of knowledge is made by a continuing evaluation of existing theories. The assembling of new evidence and the reexamination of previous evidence results in either modification of existing theories or the invention of new ones.

In this investigation you should question the adequacy of each of the proposed theories to accomplish the functions mentioned above. In so doing, you should learn more about the functions of theories and the manner in which experiments and the results of experiments may be used to evaluate theoretical models. Any determination about the relative merits of the two theories being studied will be a secondary goal.

In the course of this investigation you will have the opportunity to carry out some investigations of heat related phenomena. In many other cases because of time, equipment, or safety limitations, you will be given the results of investigations done by others. In either case you should be questioning the adequacy of each of the theories to interpret and explain these results. By the conclusion of this investigation you should be able to make a sound evaluation of the adequacy of the theories being studied.

THE THEORIES

The basic postulates of the two theories are given below. The kinetic molecular theory is usually stated for gases only, principally because of the greater complexity of matter in the solid and liquid states. The theory, as stated here, attempts to incorporate postulates about all three states of matter. This has been done in order that the theories might be presented in a form more suitable for comparison. Study the postulates of the theories with a view to finding similarities and differences.

Caloric Fluid Theory

1. Heat is an invisible, fluid substance, with no color or odor.
2. This caloric fluid occupies space and has mass.
3. Caloric fluid (heat) flows spontaneously from regions where it is highly concentrated to regions where it is less concentrated (from warmer to cooler regions).
4. Caloric fluid enters some solids, liquids, and gases more readily than others.
5. The addition of caloric fluid to matter increases the disorder in the arragement of the particles of the matter.
6. Matter changing from a more ordered to a less ordered state (solid to liquid, liquid to gas) is absorbing caloric fluid; matter changing from a less ordered to a more ordered state is releasing caloric fluid.

Kinetic Molecular Theory

1. Heat is a form of energy, which is evidenced in matter as a random motion of the individual particles (molecules).
2. Gas molecules move at very high velocities, causing many intermolecular collisions, as well as collisions with the wall of the container. The molecules of solids and liquids tend to move at lower velocities.
3. Gas molecules are very small relative to the great distance between them. At these distances there is no appreciable attraction between them.
4. Molecules of solids and liquids are close-packed, essentially in contact. In the solid state the molecules vibrate about fixed positions. In the liquid state the molecules move more freely and are not in fixed positions. The attractive force tends to be highest between molecules in the solid state.
5. No kinetic energy is lost in collisions between molecules; there is no tendency for the molecules to slow down and stop.
6. Molecules move faster as the temperature is increased.

I" you study the postulates above, you find that the caloric fluid theory conceives of heat as a substance. When heat is added to an object, this caloric fluid enters the object and it leaves the object when heat is taken away.

The kinetic molecular theory visualizes heat as a motion of the molecules in an object. When an object is heated, the molecules constituting the object move with a greater velocity.

While this may be oversimplified, the basic difference in the two theories is whether heat is visualized as a particle-fluid (caloric fluid theory) or as molecular motion (kinetic molecular theory). It should be recognized in the investigations that follow that a particular experimental result may be explained adequately by one theory, but not by the other; or it may be explained equally well by either theory.

Investigation 6.1 Temperature & Heat

At one time the terms temperature and heat were used almost interchangeably, but for many years now it has been recognized that there is a basic difference. To investigate the difference place about 400 ml of water in a 600 ml beaker. Heat this water in the beaker over a medium burner flame. At the same time that this is heating, hold an iron nail in the same flame using metal tongs. When the metal begins glowing with a red glow, remove it and hold it against a piece of paper. What do you observe? The flame has been warming the beaker of water for a longer time than the nail, but will it have the same effect on the paper? Which object is hotter, the nail or the water?

The result of this and other similar investigations would seem to make it evident that temperature is a degree of hotness, that it measures the intensity of heat. The more heat we put to a given object, the higher its temperature; the less heat in the same object, the lower the temperature. In the iron nail, the heat was concentrated in a small object. The temperature increased greatly. Even though a larger quantity of heat was added to the water, the temperature was not elevated as much, because it was distributed throughout a greater mass of material.

As an optional investigation you might fill your bath tub with hot water. Now withdraw a cup of water. Obviously, the water in the cup and in the tub must initially be at the same temperature. Do they contain the same amount of heat? You can answer this by determining the number of ice cubes each will melt. (Caution: if a parent or friend walks in during this investigation, your sanity may be questioned.) The investigation should furnish further evidence that heat and temperature are not the same.

Questions:

1. Is the heat transferred in the investigation with the nail and the water consistent with either of our theories? Explain briefly.

2. Was there any indication in either of the preceding investigations to answer the following question: "What will happen when objects at different temperatures are brought into contact?" Explain.

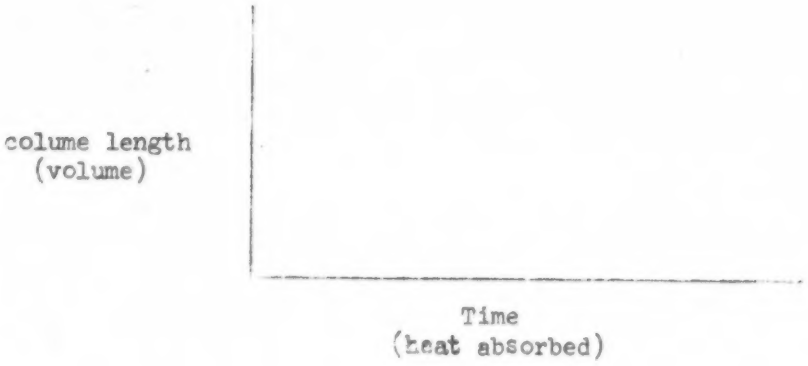
Investigation 6.2 Measuring Temperature

In the preceding investigation you found that temperature and heat are not the same. Temperature is the "degree of hotness" or measure of the intensity of heat. In this investigation you will look at ways to measure temperature.

The skin is a temperature sensing device. To determine how well it works try the following. Take three small beakers (250 ml will do). Put equal volumes of hot water, cold water, and water at room temperature into the beakers. Put one or two fingers from one hand in the hot water and at the same time one or two fingers from the other hand in the cold water. Leave them in the beakers for 30 seconds. Now withdraw them and place both in the beaker at room temperature. What do you observe? Can you explain the observation? While the skin may give relative temperatures, we need instruments for more accurate measurement of temperatures.

Thermometers make use of the fact that the volume of most materials increases with increasing temperature. To build a simple thermometer, insert a 25-30 cm length of glass tubing into a rubber stopper (moisten slightly with glycerin first). Insert the stopper into a test tube which has been filled with water. Now place the test tube in a 250 ml beaker which is half filled with water. The whole apparatus should be placed on a ring stand over a burner flame.

With a metric ruler measure and record the length of the water column every 30 seconds until the water has expanded to almost fill the glass tubing. Construct a graph plotting the length of the column (vertically) against the time (horizontally). If you can assume the tube has a uniform inner diameter, equal lengths along the tube will represent equal increases in volume. The vertical axis may then be read as volume. Another assumption that can be made is that the burner flame was practically constant. If so, then the water bath and test tube were receiving heat at a constant rate. The horizontal axis may then be read as heat absorbed (see below). What relationship do you observe between heat absorbed and volume? This device is actually a type of thermometer.



Questions

1. Could the addition of heat to the water in this investigation be explained by either of our theories? Explain briefly.
2. Commercial thermometers make use of mercury or alcohol. Why is water not used?

Temperature Scales

Temperature measurements in science are most often made using either the Celsius scale (C), sometimes referred to as the centigrade scale, or the Kelvin scale (K), also known as the absolute scale. A temperature change of one degree on the Celsius scale is the same amount as one degree on the Kelvin scale, although the two scales have their zero points at different temperatures.

The zero point on the Kelvin scales is at the temperature where it is believed there is no heat whatever in an object. This point is called absolute zero. The zero point on the Celsius scale is the freezing point of water.

Absolute zero on the Celsius scale is approximately -273°C. The scales compare as follows:

	Celsius	Kelvin
Boiling Point of water	100°C	373°K
Freezing Point of water	0°C	273°K
Absolute zero	-273°C	0°K

It should be obvious that by adding 273° to any Celsius temperature, you will arrive at the corresponding Kelvin temperature.

Questions

1. Can you see any advantage of the Kelvin scale over the Celsuis scale? If so, what?

Investigation 6.3 Change of State (optional investigation)

Blot dry several ice cubes and place them in a small beaker (250 ml). Place the beaker on a stand over a burner flame. Support a thermometer in the ice cubes so that the bulb doesn't touch the bottom of the beaker. Stir the ice cubes occasionally and frequently record the time and temperature. Also note the times when you have all ice, an ice-water mixture, all water, and boiling. Continue heating for several minutes after boiling occurs.

Plot a graph of temperature vs. time. What happens to the temperature as the ice is melting? What happens to the temperature as the water is boiling?

Questions

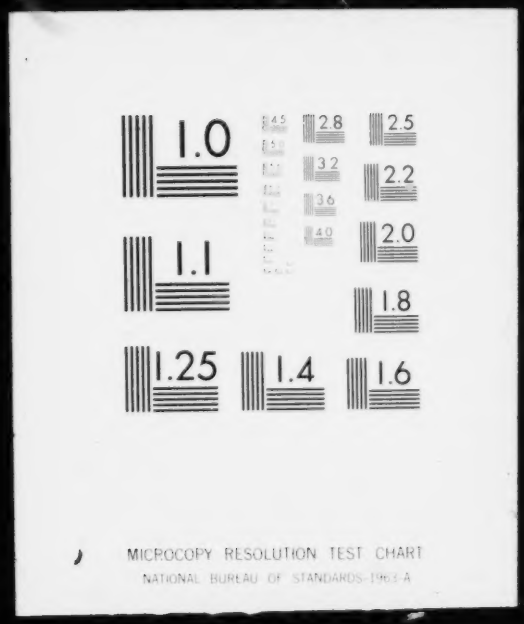
1. As the water reached the melting point in this investigation, the temperature ceased rising for a time. Where does the heat go that is added during this time? Does something similar happen at the boiling point?

A caloric fluid explanation of what you observed goes as follows. The fluid enters the solid ice and penetrates the space between the particles. As the fluid surrounds each ice particle, the attraction to neighboring ice particles is reduced. The solid breaks into a less ordered arrangement, and finally the particles flow freely in the liquid state. When enough of the heat fluid (caloric) has been added to the water, the particles of the water are more completely surrounded by heat particles. Their attraction for one another is completely overcome and they move off independently in the vapor (gaseous) state.

2. Can you give a kinetic molecular theory explanation for the results of this investigation in a manner somewhat similar to the caloric fluid explanation given above. Is either theory superior?

2 OF 3

ED 082 972



Investigation 6.4 Conservation of Heat

Repeated investigations have shown that heat will flow rather easily through some materials, less easily though others, and with great difficulty through still others. (You may demonstrate this by touching the handles of a wooden spoon and a metal spoon, both having their lower ends resting in a pan of hot liquid). Those materials through which heat will flow readly, like the metal spoon, are called conductors. Those materials which do not readily conduct heat, such as the wooden spoon, are called insulators. Optional: Try placing one end of several different types of material (wood, glass, plastic, different metals) in boiling water. After a few minutes cautiously touch the other ends. What observations can you make?

In heat studies it is often advantageous to have a container made of good insulating material. Such a container is called a calorimeter. What materials would make a good calorimeter?

Using a graduated cylinder, measure 100 ml of hot water into one calorimeter. Measure an equal volume of cold water into another. Using two thermometers measure and record the temperature in each. Pour the water from one calorimeter into the other, stir briefly, and record the final temperature. How does this final temperature compare with the two initial temperatures?

Predict what would happen if we repeated the investigation with 100 ml of hot water and 50 ml of cold water, 100 ml of cold water and 50 ml of hot water, and finally 100 ml of hot water and 20 ml of cold water. Now perform these experiments to check your predictions. What do you observe?

Repeated experiments of this type, using both water and other materials, will allow you to arrive at a very important generalization: the principle of conservation of heat. While heat flows from the warmer object to the cooler one when two objects are mixed or brought into contact, no heat is gained or lost. It is merely redistributed. Any apparent loss in an investigation such as this is usually due to a loss to the air in the room. A perfect calorimeter would prevent this.

Questions

1. Would it make any difference in this investigation if we added the cold water to the hot, instead of the hot to cold?

2. Can the results of this investigation be explained using either of our theories of heat? Explain briefly.

Heat Units

You learned earlier that temperature may be measured in degrees on a thermometer, but measuring heat involves both the temperature and the mass of substance involved. The metric unit for heat is the calorie. It is defined as the amount of heat required to change the temperature of one gram of water one degree Celsius. 1000 calories, or one kilocalorie, is the amount of heat needed to change one kilogram of water one degree Celsius. The kilocalorie is sometimes called a large Calorie and designated with a capital C.

If one gram of water is heated by 10 Celsius degrees, we have added 10 calories of heat. Fifty grams of water cooling by twenty Celsius degrees releases 1000 calories or one kilocalorie.

Questions

1. How much heat would be required to raise the temperature of 15 grams of water from 40° to 50°C? from 80° C to 90°C?
2. Thirty calories of heat was added to two grams of water at 20°C. What is the final temperature?

Gases and Heat

Most of your attention has been directed to the solid and liquid states of matter and little has been said about gases. This is an important state of matter, however, and the study of the behavior of gases may yield fruitful results.

Since investigations involving gases are often difficult to conduct, only a few simple investigations will be included here. The results of others will be reported.

Investigation 6.5 Gases and Heat

In order to investigate the effect of heat on gases carry out the following:

A. Fasten a rubber balloon over the mouth of a test tube. Heat the tube gently. What do you observe? Now allow the tube to cool to room temperature. What do you observe?
B. Fit an empty 250 ml flask with a rubber stopper and a glass tube 20-25 cm in length. Invert the flask so that the end of the tube may be placed in a beaker of water. Hold your hands around the flask. What do you observe? Now place a cool wet towel around the flask. What do you observe?

Questions

1. What happens to a gas on heating?
2. What postulates of the caloric theory might explain your observations?
3. What postulates of the kinetic molecular theory might explain your observations?

Investigation 6.6 Odors (optional investigation)

A. Smell the substances in containers A, B, and C. Can you tell anything about them? How does the smell reach your nose? Can you see anything between the container and your nose? Try covering one of the containers with various materials (cloth, plastic wrap, or foil). Can you still smell the substances? Can you see through the coverings of the containers? Can you still blow through them?

B. Place 3-4 mothballs in each of two containers. Cover one and leave the other uncovered. Find the mass of each and record. Find the mass of each on two subsequent days and record. Can you explain your observations? What is responsible for the odor of mothballs?

The fact that solid and liquid substances have odors is evidence that some particles (molecules) of the substance reach your nose. Any loss of mass that you might have found in part B above would be further evidence that some molecules are escaping. It may be puzzling that many solid objects with odors (cedar, camphor, etc.) have no appreciable loss of mass over a period of time. It has been found, however, that the nose is one of the most sensitive detection instruments known. Only a few molecules out of billions would have to leave a solid in order for an odor to be detected.

Suppose that we assume that a few particles may occasionally escape from a solid into the gaseous state. How can you account for them reaching your nose? For that matter, how can we account for the odor of a manufacturing plant across a city, the odor of onions frying in a kitchen, or the odor of a cake baking? While some of this movement of molecules is due to circulating air currents, controlled studies in relatively still rooms have shown that gases diffuse, or mix without the need for circulating air currents. You may establish this yourself by carrying out one of the following optional investigations.

Investigation 6.7 Rate of Diffusion: Gases (optional)

Hydrogen chloride (from hydrochloric acid) and ammonia are colorless gases which react to produce a white cloud of ammonium chloride.

Take a piece of glass tubing about 2 cm in diameter and 50 cm long, fitted with cork stoppers at the ends. Remove the stoppers and touch a drop of hydrochloric acid to the small end of one stopper and a drop of ammonia water to the small end of the other. Place the stoppers in the ends of the tube simultaneously and note the time. When the diffusing gases meet, they will form a white ring (ammonium chloride). Determine the length from each end of the tube to the ring and the time required. Repeat with the tube in different positions (horizontal, vertical, etc.), and with a tube that has been cooled in a refrigerator.

Questions

1. Does this investigation give evidence that gases diffuse?
2. What factors, if any, affect the rate of diffusion?

NOTE: You may wish to view the film loop on Gas Diffusion Rates at this time.

Investigation 6.8 Rate of Diffusion: Liquids (optional)

Place an equal volume of water (about 300 ml) in three 400 ml beakers. The water should be brought to widely separated temperatures. One near the freezing point, another at room temperature (about 23°C), and the third near the boiling point will do. Record the temperatures.

Carefully place a drop of ordinary ink on the surface of the water in each beaker. Record the time it takes for the ink to completely diffuse in each beaker.

Questions

1. What is the effect of heat on the rate of diffusion?
2. Many investigatiors have concluded that the diffusion of gases and liquids (and to limited degree, solids) is evidence to support a kinetic molecular theory. What postulates of that theory seem to interpret diffusion?
3. Is diffusion inconsistent with the caloric fluid theory?

Results of Other Investigations

After conducting some exhaustive studies with gases in the seventeenth century, Robert Boyles arrived at the following quantitative law:

"The pressure and volume of a gas are inversely proportional, provided the temperature is constant."

Another way to state this law is: the product of the pressure and volume of a gas is constant (PV=K). If you double the pressure on a confined gas, the volume is reduced by half. If the pressure is tripled, the volume becomes one third of the original volume. If the pressure is reduced by half, the volume doubles. If we call the initial volume V_1, the initial pressure P_1 and any subsequent volume and pressure V_2 and P_2, then we may use the following expression to solve problems involving gas volumes and pressures:

$$P_1V_1 = P_2V_2$$

Charles' Law relates gas volume and temperature in a similar manner:

"The Kelvin temperature and volume of a gas are <u>directly</u> proportional, provided the pressure is constant."

If you double the Kelvin temperature of a gas, its volume will double. If you reduce the Kelvin temperature to 1/3 of the original (from 300°K to 100°K) the volume would be 1/3 of the original volume. In mathematical form:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

where V_1 and T_1 are the original volume and temperature, V_2 and T_2 are some subsequent volume and temperature. Why can Celsius temperatures <u>not</u> be used for solving problems with Charles Law? (hint: Which scale has no negative values for temperature? What would it mean to say the temperature was doubled when it was 5°C? 1°C? Is it twice as warm at 2°C as it is at 1°C?)

Recall from your earlier readings that laws are statements concerning the regularity which nature displays. We can use these laws (Boyle's and Charles') to predict what will happen when we change the pressure or temperature of a gas, but the laws in themselves have no explanatory or interpretive function. For example, you may use Boyle's Law to predict that when the pressure on 5 liters of gas is raised from 1 atmosphere to 2 atmospheres, the volume will become 2.5 liters. Boyle's law, however, says nothing about why this happens, or of what gases are constituted, etc. It remains for theories to provide a model which will allow us to interpret and explain what is happening.

Questions

1. Which of the postulates of the kinetic molecular theory may be used to interpret Boyle's Law? Charles' Law?
2. Can the caloric theory likewise interpret these laws?

Taking Inventory

By this time you have carried out several simple investigations of heat phenomena. Several others have been described. Other investigations which you might have attempted, time permitting, would include evaporation, boiling, conduction, the solution process, and crystallization. At this point it might be helpful to summarize what has been learned from these investigations as they relate to the two heat theories.

The results of the investigations in this lesson (both those you completed and those which were reported) might be summarized as follows:

a. The more heat we add to an object, the higher the temperature will go. The more heat we remove, the lower the temperature will go.
b. Some objects undergo greater temperature changes than others when receiving the same amount of heat. At least one factor that influences this temperature change is the mass of the object. Another may be the type of material.
c. Heat always seems to flow from objects at higher temperatures to objects at lower temperatures.
d. Most substances expand when heated and contract when cooled. This change of volume is greatest in the gaseous state.
e. The addition of heat may cause a change of state from solid to liquid or liquid to vapor. The loss of heat may cause a change of state from vapor to liquid or liquid to solid. When such a gain or loss of heat is causing a change of state, it does not show up as a change in temperature.
f. Heat will flow easily through some materials (conductors) and with difficulty through others (insulators).
g. While heat may flow from one object to another, it is conserved; that is, none is gained or lost in the process. It is merely redistributed.
h. Gases, and to a lesser extent liquids and solids, diffuse or mix without the aid of external agitation or gravity. An increase in temperature will increase the rate at which they diffuse.
i. The pressure and volume of a gas are inversely proportional at constant temperature.

While this list might be longer, it will serve as a basis for comparing the theories at this time. If you refer to your answers to the questions included in these investigations, you should come to the conclusion that for interpreting and explaining these results, the two theories serve equally well. Recall that theories are seldom, if ever, judged "right" or "wrong".

You are still left with the problem of deciding if one theory is more acceptable than the other. Historically, there have been investigations in only two areas which would shed light on this problem. Unfortunately the investigations which would be most helpful are difficult. For the most part the results of these investigations will be reported.

Mass

The caloric fluid theory, viewing heat as composed of particles, requires that an object gain mass when heated. It has probably already occurred to you to investigate to see if this is true. There are several difficulties with carrying out such investigations, such as:

a. Attempts at measuring the mass of hot objects might be affected by convection currents set up around these objects.
b. The added mass might be so slight as to be undectectable by available instruments.
c. The particle fluid might have no mass or negative mass. (We may find this difficult to accept today, but historically there are precedents. Recall your investigation of the phlogiston theory)

The results of many investigations have established that there is no change in mass (or weight) when an object is heated or cooled. (See pages 153-154 and 158-162 of optional reading 1 for descriptions of some 18th century investigations). Having finally established that heat has no mass, you might expect that the caloric theory would be immediately dismissed. This did not happen for two reasons. The theory served well to explain most of the known heat phenomena. The second reason is given in c. above (particles with no mass or negative mass).

Heat from Friction

The finding that heat has no mass was a blow to the caloric theory, but by no means a serious obstacle. In addition to the reasons cited above, some of the early investigations of mass were contradictory. It remained for investigations involving heat and friction to offer more conclusive evidence concerning the nature of heat.

The best known of these investigations were those conducted by Count Rumford (Benjamin Thompson) concerning the heat produced from the boring of cannons. He was supervising the boring of cannons in a military arsenal at Munich, when he noticed the great rise in temperature of the metal shavings left in a cannon by the boring tool. Many others had previously noted heat produced in a similar manner, but Rumford had an inquiring mind and some scientific training, which may explain his need to investigate further.

In his best known investigation Rumford pressed a blunt boring tool against the inside of a cannon. The cannon was turned by horses against the stationary boring tool. After 30 minutes of turning, the temperature had risen from 60° to 130° F, in spite of the fact that only 837 grains (about .12 lb) of metallic scale was detached from the cannon. He found this hard to reconcile with the caloric fluid theory. Why?

As a result of many similar investigations, Rumford concluded that the only reasonable explanation for the heat produced by friction was that afforded by the kinetic molecular theory. The mechanical energy used in turning the cannon was converted to a motion of the particles (molecules) of the metal. For a complete account of Rumford's experiments see pages 169-189 of optional reading 1.

In another experiment by Rumford, heat generated by friction caused water to boil. Sir Humphry Davy melted some blocks of ice by rubbing them together on a day when the temperature was below freezing. Davy's investigations are described beginning on page 189 of optional reading 1.

It is difficult to perform quantitative investigations of the heat produced by friction, such as those described above, and get good results for a variety of reasons. On the other hand, there are countless examples of qualitative investigations you can perform. For that matter, there are many everyday phenomena which illustrate the production of heat from friction. To name a few: warming your hands by rubbing them together, the heat produced when metal machine parts, such as gears, move together (especially without lubricant), starting a fire by rubbing two sticks together, etc. Can you add any others?

Conclusion

The caloric theory was an ingenious theory, and in an earlier time, explained all of the known phenomena. It was "right" or "true" in the same sense that any scientific theory is "true". It is still convenient to think of a "fluid" being transferred to an object that is being heated. However, the well planned experiments involving mass and friction yielded results not explainable by the existence of caloric. The ability of the kinetic molecular theory to explain these phenomena have made it the accepted theory in the past century.

Additional Questions

1. State the basic postulates or assumptions of the caloric fluid theory. Can you cite at least one item of evidence from everyday experience to support each?

2. State the basic postulates or assumptions of the kinetic molecular theory and cite at least one item of evidence from everyday experience to support each.

3. What investigations can you cite which cannot be explained adequately by both theories? Which theory is more acceptable? Explain.

4. What is meant by an elastic collision? Why must you make the assumption that collisions between gas molecules are perfectly elastic?

5. How does the kinetic theory explain the fact that gases exert pressure on every surface with which they come into contact?

6. Simply state Boyles Law. How does the kinetic molecular theory explain the law?

7. Simply state Charles Law. What is the kinetic molecular theory explanation?

8. What happens when heat is added to a gas in a closed rigid container? Why? In an elastic container like a balloon? Why?

9. The balloons that are used for weather study are very large. When released at the earth's surface they contain a relatively small volume of gas compared to the volume they acquire aloft. What is the explanation?

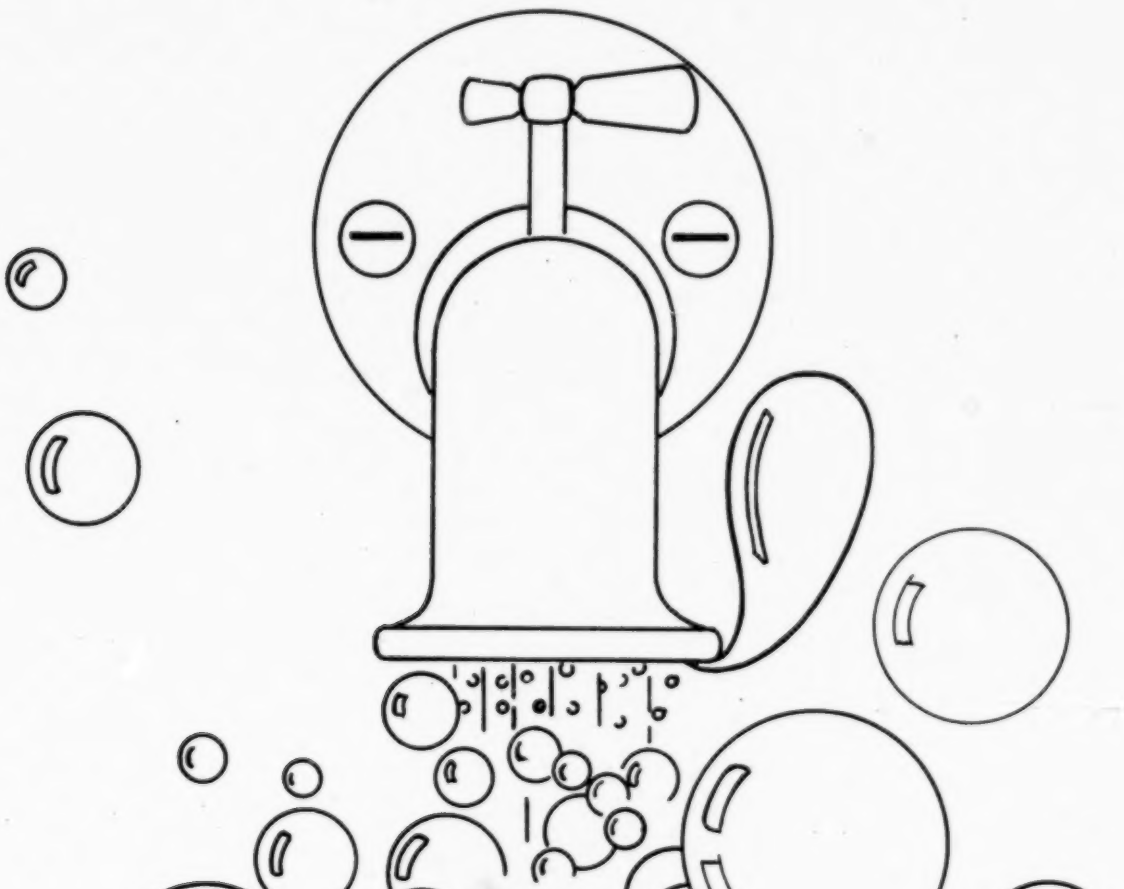
10. How much heat, in calories, is given off by 200 g of water in cooling from $100^{o}C$ to $10^{o}C$?

11. Ten grams of water at 5^{o} C is given 20 calories of heat. What is the temperature?

12. A quantity of nitrogen gas occupies a volume of 12 liters at 1 atmosphere pressure. What volume will it occupy if the pressure is increased to 3 atmosphere? 4 atmospheres? 12 atmospheres? (assume the temperature remains constant).

13. What will happen to the same quantity of nitrogen gas (preceding question) if the temperature (Kelvin scale) is doubled? tripled? (assume the pressure remains contant).

Lesson 13



The Detergent Dilemma: A Science & Society Study

LESSON 13. THE DETERGENT DILEMMA:

A SCIENCE AND SOCIETY STUDY

Instructional Objectives Following the completion of this lesson you should be able to:

A. Recognize the structural features common to soap and detergent molecules and describe how the cleansing action is based on these structural features.
B. Recognize the natural substances which are used to produce soap and the method of preparation.
C. Describe what is meant by hard water and recognize the ions responsible.
D. Describe how water softeners work.
E. List or recognize the three basic classes of substances found in commercial laundry preparations, and give examples.
F. Recognize why detergents are superior to soap.
G. Discuss the eutrophication problem including what it is, the danger to the environment, and the nutrients which may be responsible.
H. Recognize some possible solutions to the phosphate problem as well as the disadvantages of each.
I. Discuss the role which should be played by each of the following in combatting a problem such as the phosphate problem: government, industry, the public, scientists.
J. Discuss the implications of a sudden and total ban on the sale of detergents containing any phosphates.
K. Discuss the question "Is science good or evil", using examples from your readings in this or previous lessons.

Core Activities

A. Readings
   1. "Soap, Detergents, and Hard Water," included with this lesson guide.
   2. "Why Detergent Makers are Turning Gray," Business Week, 20 Feb. 71, pp. 64-66.
   3. "Phosphate Replacements: Problems With The Washday Miracle," Science, Vol. 172, 23 April 71, pp. 361-363.
   4. Kieffer, W. F., Chemistry, A Cultural Approach, pp. 411-414, 421-429.

B. Questions
   1. Included with this lesson guide.

C. Laboratory Activities
   13.1 An Investigation of Hard Water

Optional Activities

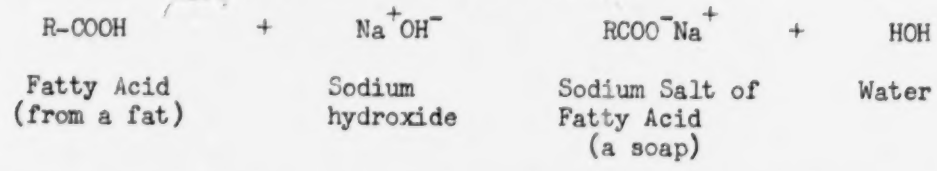
A. Readings

1. Kieffer W. F., Chemistry, A Cultural Approach. Chapter 16.
   This chapter deals with most of the environmental problems currently begging for solutions.
2. Jones, Mark M., et. al., Chemistry, A Brief Introduction, pp. 260-263.
   The sections on Fats, Oils and soaps, and Synthetic Detergents are brief, but should prove helpful.
3. Keller, Eugenia, "The DDT Story," Chemistry, Vol 43, Feb. 70, pp. 8-12.
   While not directly related to the detergent problem, DDT is a water polluter of major consequence. This article provides a brief, but interesting case study.

Soap, Detergents, and Hard Water

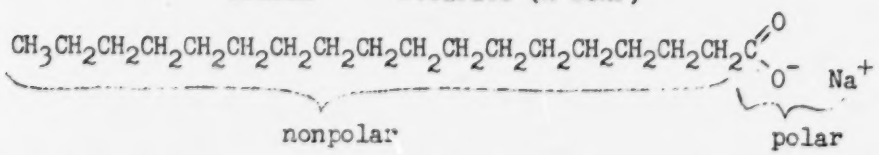
Soap

Natural soaps are prepared by reacting fats or oils from plant or animal sources with a strong alkali such as lye (NaOH).



In the general equation shown above the R represents a long chain hydrocarbon fragment of from 10-18 carbon atoms with hydrogen atoms attached. A typical soap is sodium stearate produced from the animal fat stearin.

Sodium Stearate (A SOAP)

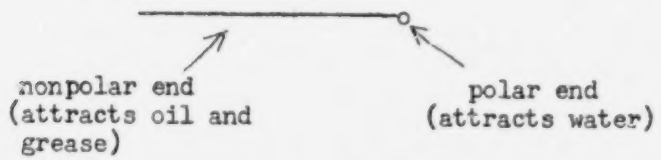


In an earlier lesson you learned that water molecules are polar and that the attraction of water molecules for each other (hydrogen bonding) was due to the attraction of one polar molecule for another. The polar end of the soap molecule tends to make it water soluble (hydrophilic or attracted to water).

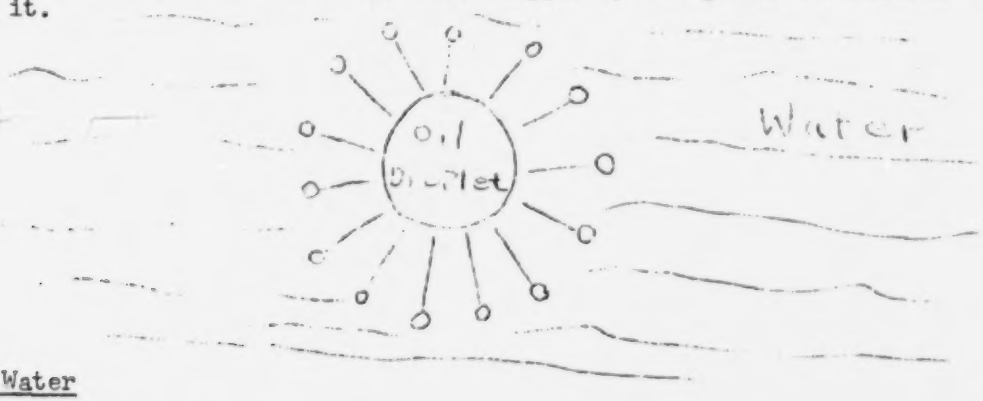
Oils and water do not mix. Oils, including the natural oils of the skin, are nonpolar molecules which are not soluble in the polar water molecules, but will dissolve in nonpolar solvents such as gasoline. These skin oils tend to trap dirt particles and plain water is ineffective in removing this greasy layer.

When soap is added to the water, the long hydrocarbon "tails" (the region marked nonpolar on the sodium stearate molecule above) will attract the oil molecules, while the polar ends of the soap molecules will attract the water molecules. The oil or grease is broken up into small droplets and can be rinsed away.

If we use the following simplified drawing for the soap molecule:



then the following drawing will show how a grease or oil droplet can be emulsified and rinsed away. Any dirt trapped by the grease is removed with it.



Hard Water

If certain ions are present in the water (principally Ca^{+2}, Mg^{+2}, or Fe^{+3}) an ordinary soap will precipitate as an insoluble salt and the water is said to be hard. Scum in the washing machine and a ring on the bath tub are visible signs of this precipitate. In word equation:

Sodium Stearate + Calcium ions → Calcium stearate ↓ + Sodium ions

(soap) (scum, an insoluble salt)

Not only is the scum undesirable, but additional soap must be added to make up for the soap lost in this process.

Detergents

Detergents are synthetic molecules which have been designed according to the principles mentioned above under the mechanism of soap action; that is, they are molecules with a long carbon chain (12-18 atoms) and a highly polar group at one end. The primary difference is that these detergent molecules do not form the sticky, insoluble precipitates (scum) when used in hard water. They do offer other problems which are discusses in readings 2 and 3.

A typical commercial laundry detergent is actually composed of three basic types of compounds: builders, surfactants and miscellaneous additives.

Surfactants - This refers to the synthetic soap-like molecules described above. Their job is to emulsify and float away dirt. They are poisoned, however by ions such as calcium and magnesium, present in hard water.

builders - These are compounds whose job it is to sequester, or tie up, the calcium and magnesium ions which would interfere with the surfactant. Phosphates are excellent builders, except for their environmental effects. More on this in readings 2 and 3.

miscellaneous - This includes brighteners, perfumes, enzymes, etc.

Experiment 13.1 An Investigation of Hard Water

You learned in the readings that certain ions in water make it hard ("hard" to produce suds). In this investigation you will have an opportunity to measure the degree of hardness of various water samples by measuring the amount of a soap solution necessary to produce a permanent "lather" or suds.

A. Place in a 250 ml flask a sample of 40 ml of distilled water. To this add 10 drops of the soap solution. Place a clean rubber stopper in the flask and shake for two minutes. If a stable "lather" is not produced, add another 10 drops and again shake the flask. In this manner, continue to add soap solution until a stable lather persists for 1 minute after shaking. Record the number of drops required for the distilled water sample. Rinse the flask.

B. Place a 40 ml sample from the bottle marked "hard water" into the flask. This has been prepared by adding a calcium compound to distilled water. Proceed to determine the amount of soap required to produce a stable lather in the same fashion as in Part A. (10 drops of soap at a time). Record the number of drops required.

C. Again place a 40 ml sample from the bottle marked "hard water" into the flask. This time add .2 gram of solid sodium carbonate (washing soda), a commercial water "softener". Swirl this around in the flask. Do you observe anything? Now proceed to determine the amount of soap required to produce a permanent lather in the same fashion as before. Record the number of drops required.

D. Repeat the procedure described in Part A with a 40 ml sample of tap water. Record the number of drops required.

E. Optional Perhaps you can suggest other samples which you will want to submit to this test. If you have a commercial water softener at home, you might bring in a sample of this water to test. If your water supply is from a different source than the tap water used, you might compare it. Can you suggest other possibilities?

1. What general conclusions can you draw from an examination of your data?
2. Does the addition of a water softener cause a precipitate with the ions in hard water? If so, why is this precipitate any less objectionable than that formed with soap and hard water?
3. Do you feel that an investigation such as this could be used successfully in the elementary school?

Questions: Lesson 13

Questions 1 to 7 deal with the material presented in core reading 1 and Experiment 13.1.

1. What structural features are found in a soap molecule? How is this responsible for the cleansing action?

2. How are natural soaps prepared?

3. Why will the addition of a strong alkali such as lye (sodium hydroxide) aid in unstopping a greasy sink drain?

4. What ions are responsible for "hard" water?

5. How can hard water be combatted?

6. How are detergents superior to soap?

7. What are the three basic classes of compounds found in most commercial laundry detergents? What is their function?

Questions 8 to 18 are based on core readings 2 and 3.

8. We hear so much about phosphates in laundry detergents. Into which of the three classes mentioned in question 7 would the phosphate additives fall?

9. Why have phosphates come under attack?

10. What is entrophication? What causes it?

11. What substitute for phosphates was briefly used during 1970? Upon what piece of research was its discontinuance based?

12. Should the phosphate content be carried on the label of laundry products? (As an optional excercise, check the laundry products on the shelf of a supermarket. How many mention the presence or absence of phosphates? Do any list the percentage of phosphates?)

13. According to core reading three, some small companies have used precipitating "builders" in place of phosphates. What disadvantages occur?

14. List three or four possible solutions to the phosphate problem and a disadvantage of each.

15. Should it be the responsibility of the government or industry to carry on research in the area of non-polluting detergents?

16. Do we need laws to govern the ingredients used in laundry products? Who should police them?

17. Which of the following parties is responsible for the phosphate problem?

    a. the scientists who developed these synthetic detergents.
    b. the companies who produce them.
    c. the government for not adequately regulating the use of phosphates.
    d. the housewife in search of cleaner clothes.

18. What disadvantages are there in returning to the use of natural soap in place of using detergents?

Questions 19 and 20 refer to core reading 4.

19. Why are some people now referring to the earth as a space capsule? (core reading 4)

20. Is science "good" or "evil"? Discuss briefly.

ADDENDUM TO LESSON 13

If you have struggled through the readings in this lesson, you are bound to have been impressed by the absurdity of the entire detergent controversy. Phosphates are singled out as pollutants and a search for substitutes initiated. NTA is hailed as a safe substitute and at least one company invests heavily in its manufacture. Almost as soon as NTA products go on the market, the government pressures the manufacturers to discontinue its use. Maybe phosphates aren't so bad after all (at least until a safer substitute is found). Meanwhile some smaller companies market highly alkaline, no-phosphate detergents. Perhaps these are more dangerous than the earlier products they were to replace. Some authorities have attacked the research (upon which the removal of NTA from the market was based) as being poorly done or too limited in scope. All along there have been those who have claimed that phosphates from detergents are a small percentage of the phosphates put in the environment and that they are not a serious polluting agent. Others claim the answer is in the removal of phosphates in the sewage treatment process.

There are probably many lessons to be learned from an examination of the blunders committed in handling the detergent controversy. The final chapter of this story is yet to be written.

In the short time since lesson 13 was written, several additional articles have appeared. A few additional activities for your consideration are:

1. "Sudsy Dilemma," Newsweek, Jan. 17, 1972, pp. 62-65.
2. "The Phosphate, No-Phosphate Controversy," Consumer Bulletin, June, 1972, pp. 26-27.
3. "A Phosphate Ban Gets Court Backing," Business Week, June 24, 1972, p. 29.
4. Cleaning Our Environment; The Chemical Basic for Action, American Chemical Society, 1969. Section 2 deals with all aspects of the water environment. The phosphorus issue is treated on pp. 131-132. Eutrophication is dealt with on pp. 149-151.

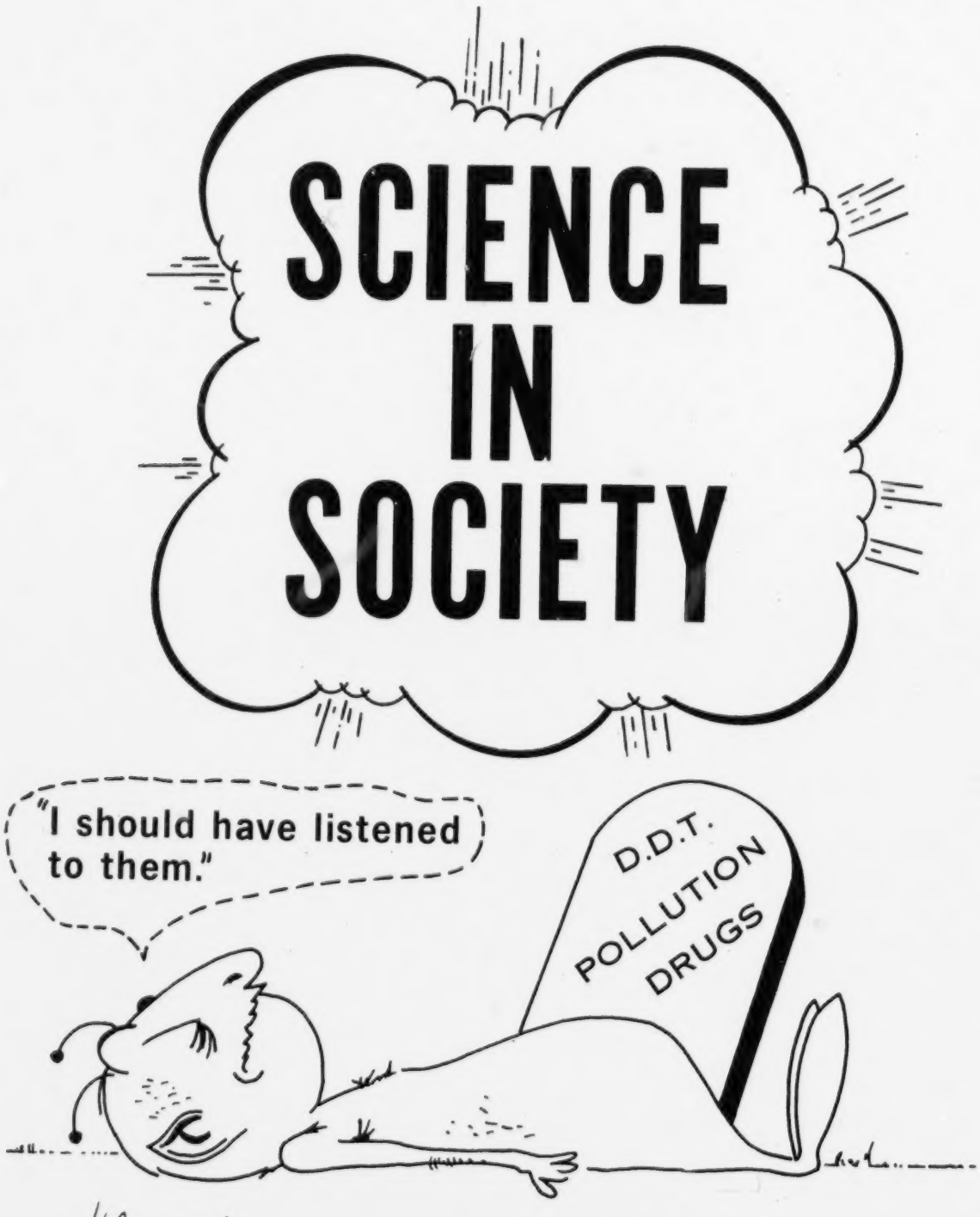
*5. "Soap: Some Companies' Answer to Phosphate-Containing Detergents," Chemical and Engineering News, Vol. 49, Aug. 17, 1970, pp. 18-19.

*highly recommended

**6. "Clean Water", a filmstrip and accompanying pamphlet produced by the Procter and Gamble Co.

**The viewing of this filmstrip is highly recommended; particularly the latter portion where the eutrophication problem is

investigated in a series of tests. You should remember as you view this strip that is was produced by one of the nations leading produceres of detergents. This is not to suggest that they have presented a biased viewpoint. Any decision in that regard will be left up to you. You should scrutinize their tests for the use of sound inquiry techniques.


SCIENCE IN SOCIETY
"I should have listened to them."
D.D.T.
POLLUTION
DRUGS

The Chemicals in Our Foods

An Optional Lesson

Since this lesson is one of the optional assignments in this course, you will find it much less structured than the other lessons. You have freedom to pursue this topic or another topic of your choosing in whatever manner you feel is best. To add to the freedom of choice, there are no instructional objectives included with the optional assignments and no test questions will be based directly on the optional material. Hopefully, however, the pursuance of the optional material will help in achieving some of the competencies stated in other lessons; for example, instructional objectives 12.F., 12.H., 12.I., 12.J., 13.I., and 13.K. If you choose to investigate this topic, you are asked to give the instructor a copy of your responses to a minimum number of questions, as directed in the instructions with the questions, or submit a brief written report of your investigation. You should also hand in a list of the activities you complete.

Introduction

The task of providing an adequate food supply for the world's population is of increasing concern. You will notice that the materials listed below were not designated as "core" and "optional" as they were in previous lessons. The reason for this is that by a proper choice of materials, you may focus your investigation on one of a variety of subtopics. Some possibilities are:

1. The Chemistry of Nutrients (fats, proteins, carbohydrates, vitamins, etc.)

2. Chemical Food Additives

3. Natural Foods or Synthetics (Which is best? Is there a clear-cut distinction?)

4. How Can We Feed an Ever Increasing World Population?

You should find that in pursuing this topic, you will encounter many other related environmental problems, such as chemical pesticides (which have several effects on our food supply), water pollution (perhaps from agricultural chemicals), or any of several others.

Readings

1. Borgstrom, Georg, The Hungry Planet, the Macmillan Co., 1965
   There are many excellent topics in this book. The ones you might choose will depend on the direction you wish to take in pursuing this lesson. A few of these topics are: The True Hunger Gap and the Calorie Swindle, the Protein Crisis, Cultivation of the Sea, and New Foods and Synthetic Nutrients.

2. Brownell, L.E., "New Approaches to the World Food Problem," The Science Teacher, March 1970, pp. 23-25.
This article reports on several interesting possibilities in improving the quality of the world's food supply. The entire March 1970 issue of The Science Teacher is devoted to food, nutrition and the world's food supply.

*3. "Even Some Chemicals That Occur Naturally in Foods Can Be Harmful," Chemical and Engineering News, July 12, 1971, p. 18.
Very brief (one page) article pointing out the hazards of some natural foods. The distinction between synthetic and natural foods may be hard to make.

4. "Everyday Facts About Food Additives," published by Manufacturing Chemicals Association.

5. Hill, John W., Chemistry for Changing Times, Burgess Publishing Co., 1972.
Chapter 10, "The Food We Eat: A Collage of Chemicals," describes the chemical constitution of the classes of nutrients; this chapter also discusses the consequences of food processing (what is removed and added).

6. Jones, Mark M., Et. Al., Chemistry, Man and Society, W.B. Saunders Co., 1972
The first part of Chapter 22 (pp. 504-521) deals with the chemistry of cooking, preservation of foods, and chemical additives.

7. Kieffer, William F., Chemistry, A Cultural Approach, Harper & Row, 1971.
The first part of Chapter 13, "The Molecules of Life," discusses the chemical makeup of fats, carbohydrates, and proteins. pp. 315-337.

8. Leverton, Ruth M. "How Good is American Nutrition," The Science Teacher, March 1970, pp. 16-19.
Reports on the nutritional adequacy of the American diet by sex, age group, and income level.

9. Lowenberg, Miriam E., Food and Man, John Wiley and Sons, 1968.
This book is a suitable textbook for an introductory course in food and nutrition. A good reference source.

10. Mooney, Booth, The Hidden Assassins, Follett Pub. Co., 1966.
An examination of the chapter titles is in order to determine which chapters will be most appropriate for your investigation. This book deals mainly with chemicals in foods, both natural chemicals and additives.

*11. Sanders, Harold J., "Food Additives Makers Face Intensified Attack," Chemical and Engineering News, July 12, 1971, pp. 16-23
This article describes the problem that food additive makers face in answering criticisms of consumer groups. The role of the Food and Drug Administration in the food additive industry is also explained. Specific additives which are discussed include monosodium glutamate (MSG), cyclamates, saccharin, sodium nitrite, and sodium nitrate.

* These will be found on reserve in the library reprinted Our

12. Sanford, David, "The Chemical Breakfast," The New Republic, August 29, 1970, pp. 12-15
This article focuses attention on the controversy over adding vitamins to cereals. The question of how much nutritional value a breakfast food should have is considered. Other breakfast items are also mentioned.

13. Scrimshaw, Nevin S., "Food," Scientific American, Sept. 1963, pp. 72-80.
This article deals with the problem of adequately feeding the world's population.

14. Sebrell, William H., and Haggerty, James J., Food and Nutrition, Time-Life Books, 1967.
This Life Science Library book is especially rich in color and black and white illustrations. Topics treated include nutrition, digestion, vitamins, and food fads and frauds.

15. Simeons, A.T.W., Food: Facts, Foibles, and Fables, Funk & Wagnall's, 1968
While this entire book deals with the food question, Chapter 6, Modern Man and His Food, and Chapter 7, The Future of Human Feeding, are especially good.

Filmstrips

1. Food Through the Ages, 35 mm. silent.
The development of knowledge concerning food from the cave-age to the present is documented.

2. Science Tells Why--Food Additives, 35 mm. silent.
Explains why foods contain additives, the sources of these additives, and the role of industry and government in safety monitering.

Questions

You may answer three or more of the following questions to complete this assignment, or you may choose instead to submit a brief written report of your investigation. The reason so many questions have been included below, is to accomodate the wide variety of approaches available in this lesson.

1. Describe and give an example of:

   a. fat
   b. carbohydrate
   c. protein
   d. vitamin
   e. mineral

2. Discuss the contributions to a good diet of the various substances listed in Question one.

3. Which of the substances listed in Question one could be classified as natural polymers?

4. How many reasons can you give for the addition of chemicals to food?

5. Examine the label of several of the following and make a list of additives found in each. Can you determine the function of the additives?

   a. canned fruit
   b. bread (white, brown, diet)
   c. canned soup
   d. baby food
   e. soda pop (regular, diet)

6. How do items get on the GRAS (generally recognized as safe) list? Are they ever removed? Who maintains the list?

7. Who do you think should conduct research to determine the safety of food additives? Why?

8. Do you think it is necessary for people in the United States to take vitamin and mineral supplements?

9. Is there any harm in the indiscriminate addition of vitamins and minerals to foods? (such as fortified cereals, bread, milk, etc.)

10. List several methods for improving the quantity and quality of the world's food supply. Comment on the pros and cons of each.

11. What are the advantages and disadvantages of eating "natural" foods as opposed to those containing additives?

The Pesticide Dilemma

An Optional Lesson

Since this lesson is one of the optional assignments in this course, you will find it much less structured than the other lessons. You have freedom to pursue this topic or another topic of your choosing in whatever manner you feel is best. To add to the freedom of choice, there are no instructional objectives included with the optional assignments and no test questions will be based directly on the optional material. Hopefully, however, the pursuance of the optional material will help in achieving some of the competencies stated in other lessons; for example, instructional objectives 12.F., 12.H., 12.I., 12.J., 13.I., and 13.K. If you choose to investigate this topic, you are asked to give the instructor a copy of your responses to a minimum number of questions, as directed in the instructions with the questions, or submit a brief written report of your investigation. You should also hand in a list of the activities you complete.

Introduction

There is no question but that the use of chemical pesticides is one of the most perplexing environmental problems of our time. On the one hand, the yield of crops has been greatly increased by their use; on the other hand, the environmental effects may be too costly a price to pay for the control of insects. Enough readings have been included in this lesson for you to have a wide selection in pursuing this topic. You may focus on a particular aspect of the problem, such as the alternatives to the use of chemicals or the testing which should precede the use of a new pesticide, or you may choose to pursue the topic in general.

Many of the core and optional readings listed are confined to the discussion of DDT. There are many other readings to be found which deal with other chemical pesticides. Perhaps you will want to search for some of these. Another interesting possibility would be to search for very recent articles on the topic of pesticides.

Core Activities

Readings

* 1. Keller, Eugenia, "The DDT Story," Chemistry, Feb. 1970, pp. 8-12.
This article briefly describes the development and early use of DDT, the growing awareness of the harm it can do, the way it is transported, and some of the effects on living organisms.

** 2. Knapp, Carol, "Choices Are in the Offing," Environmental Science and Technology, May 1971, pp. 399-403.
Briefly describes several alternatives to chemical methods of controlling pests. A good article.

* On Library reserve.

** This will be found on reserve in the Library on pages 197-202 of Our Chemical Environment.

3. Lykken, Louis, "Chemical Control of Pests," Chemistry, July/Aug., 1971, pp. 18-21.
   Similar to reading 1, but instead of limiting the topic to DDT, this article deals with chemical pesticides in general.

Optional Activities

Readings

1. Carson, Rachel, Silent Spring, Houghton Mifflin Co., 1962.
   This is the book that caused so much controversy and drew attention to environmental issues when first published. Chapter 3, as well as several other chapters, is relevant to this lesson.

2. Cleaning Our Environment: The Chemical Basis for Action, American Chemical Society, 1969.
   Section 4 is a report on pesticides in the environment.

3. Graham, Frank, Jr., Since Silent Spring, Houghton Mifflin Co., 1970.
   As the title indicates, this work deals with the questions and controversies raised by Silent Spring. The increasing public and governmental concern with environmental issues, as well as what has been done about this concern, is documented.

4. McCaull, Julian, "Questions for an Old Friend," Environment, July/Aug. 1971, pp. 2-9. Hazards of DDT, esp. effects on man.

5. Nisbet, Ian C.F., and Miner, Dallas, "DDT Substitute," Environment, July/Aug. 1971, pp. 10-16.
   Carbaryl has been recommended as a "safe" substitute for DDT. This article raises some doubt.

6. Shea, Kevin, "Infectious Cure," Environment, Jan/Feb 1971, pp. 43-45.
   A report on one of the alternatives to DDT: The use of viruses to control insect pests.

7. Shea, Kevin, "Old Weapons are Best," Environment, June 1971, pp. 40-49.
   Another alternative to DDT is treated in this article: The use of natural enemies.

8. Stoker, H. Stephen, and Seager, Spencer L., Environmental Chemistry, Scott, Foresman and Co., 1972.
   Chapter 12 on "Synthetic Organic Insecticides" gives a good overview of the classes of chemicals used in pesticides, toxicity, degradation, biological effects, etc.

9. Turk, Turk, and Wittes, Ecology, Pollution, Environment, W. B. Saunders and Co., 1972.
   Chapter three, "Pesticides," is similar in scope to reading 7 (above).

10. Warster, Charles F., "Aldrin and Dieldrin," Environment, Oct. 1971 pp. 33-41.
A report on two chlorinated hydrocarbons which are potentially more harmful than DDT.

11. Wilbur, Charles G., The Biological Aspects of Water Pollution, Charles C. Thomas, Publisher, 1969.
Similar in nature to readings 7 and 8, but much more comprehensive. The use of statistical tables is prevalent.

Questions

Answer at least five. You may choose to make a brief written report of your investigation of this topic in place of answering these questions.

1. What did man do about insect pests before chemical pesticides were available?

2. Many chemical pesticides are said to be "broad spectrum." What does this mean? What are their advantages and disadvantages?

3. What are some of the alternatives to the use of chemical pesticides for controlling insects? Explain briefly how one of these alternatives works.

4. Why may pesticides be more harmful to predators than to the insect pests they are designed to control?

5. Why is it sometimes necessary to increase the amount of pesticide used after it has been used for a period of time?

6. Which classes of pesticides are most and least biodegradable? What are the advantages of each?

7. While there are many alternatives to the use of chemical pesticides (see Question 3), progress in using these alternatives has been slow in coming and will likely continue to be. Why?

8. Who do you think is most responsible for determining what constitutes safe usage of pesticides? (the government, research scientists, the agricultural community, etc.) Defend your answer.

The Drug Hang Up

An Optional Lesson

Since this lesson is one of the optional assignments in this course, you will find it much less structured than the other lessons. You have freedom to pursue this topic or another topic of your choosing in whatever manner you feel is best. To add to the freedom of choice, there are no instructional objectives included with the optional assignments and no test questions will be based directly on the optional material. Hopefully, however, the pursuance of the optional material will help in achieving some of the competencies stated in other lessons; for example, instructional objectives 12.F., 12.H., 12.I., 12.J., 13.I., and 13.K. If you choose to investigate this topic, you are asked to give the instructor a copy of your responses to a minimum number of questions as directed in the instructions with the questions, or submit a brief written report of your investigation. You should also hand in a list of the activities you complete.

Introduction

The use and abuse of drugs is one of the most debated and controversial questions of our time. The only aspect of the question on which there is widespread agreement is that we do have a problem of major proportions. The readings have not been designated as "core" or "optional" in this topic. This is to allow you freedom to pursue the topic as you wish. You may choose to concentrate on the topic of prescription and non-prescription medicines, the use of narcotic and similar drugs for the effects they produce, or on the psychological and social effects of drug usage. The readings listed below, especially those from periodicals, are only a small sampling of those available. You should consult the Readers Guide and other indexes for articles suitable for your investigation.

Readings: Books

1. Cain, Arthur H., Young People and Drugs, John Day Co., 1969
   This book is written by a social psychologist and counseling therapist. Chapter 1 deals with the chemistry of drugs. Chapter 2 discusses the medical implications. The remainder of the book deals with the psychological, social, and religious significance of drugs and the drug problem.

2. Cohen, Sidney, The Drug Dilemma, McGraw-Hill, 1969
   This book was written for those who teach and counsel students. Much of the material was developed from questions asked by high school and college students. It is intended as a source of relevant information about drug use and misuse.

3. Hill, John W., Chemistry for Changing Times, Burgess Publishing Co., Chapter 14, "Drugs: To Cure, To Calm, To Kill."
   Deals in a limited way with pain killers, antibiotics, hormones, "the Pill," narcotic drugs, and addiction. Some of the physiological effects of drugs are described.

4. Jones, Mark M., et. al., Chemistry, Man and Society, Saunders & Co., 1972, pp. 521-536.
   This reading deals with pain killers, antibiotics, antihistimines, birth control pills, antacids, etc. Structure and physiological effects are briefly treated.

5. Laurie, Peter, Drugs--Medical, Psychological, and Social Facts, Penguin Books, 1967.
   This is an attempt to "sum up the major points of our knowledge, and still more our ignorance, about drugs." It is written by a layman and is a nontechnical work. It deals as much with the social aspect as with the medical aspect of the topic.

6. Levy, Marvin R., Project Director, Resource Book for Drug Abuse Education, American Association for Health, Physical Education, and Recreation, 1969.
   As the name would indicate, this is a collection of papers by medical authorities and social scientists which deal with the major drugs of abuse, addiction, and all of the psychological and social ramifications of drug use. A chart is found on pp. 34-35 listing drugs, medical uses, symptoms and dependence potentials. A good resource.

7. Mintz, Morton, By Prescription Only, Beacon Press, 1967.
   While several of the other references deal with the use of drugs for "effects," addiction, etc., this work deals primarily with the "legitimate" drug industry, prescription drugs, and medical uses, and the role of the FDA in regulating and testing of drugs.

Readings: Periodicals

8. "Drug Abuse and the School Scene," The Science Teacher, Sept. 1970, pp. 45-50.
   A collection of three articles presented at a drug symposium held at the 1970 meeting of the National Science Teachers Association. The individual titles are:
   "An Educational Philosophy for Drug Abuse Programs"
   "Drug Abuse Education--the Picture in New York City"
   "Inservice Education for Teachers"

9. "The Drugged Americans: Aspirin Poppers Not Spared," Science News, Jan. 1, 1972, pp. 7-8.
   Is there an overuse or abuse of legitimate prescription and non-prescription drugs? Will overuse of legitimate medications influence young people to try pill-popping? These and similar questions are explored in this brief article.

10. "Drugs and the Caltech Student," Chemistry, Nov. 1969, pp. 8-18.
    This is a reprint of a pamphlet prepared for students at the California Institute of Technology. It is addressed to students, having been written by a committee of faculty, students, and administration. It contains a clear delineation of the legal, medical, and psychological aspects of the drug issue.

11. Furlong, William Barry, "How Speed Kills Athletic Careers," Today's Health, Feb. 1971, pp. 30-33+.
Case studies document the effects that drugs can have on athletes. Also included are letters from drug users.

12. Land, Herman W., "How a Parent Can Reach His Child About Drugs," Today's Health, Aug. 1971, pp. 42-45.
This article is primarily concerned with marijuana. Is it as safe as alcohol? Is it habit forming? What are the psychological and social effects of usage?

13. "Narcotic Antagonists: New Methods to Treat Heroin Addiction," Science, 6 Aug. 71, pp. 503-506.
Should chemical agents which block the effectiveness of narcotic drugs be used in treating addiction? This possible solution is compared with other addict treatment programs.

14. Wassersug, Joseph D., "Diseases You Can Get From Medicines," Science Digest, June 1971, pp. 80-84.
Aspirin can cause allergic reactions or bleeding of the stomach. Penicillin causes allergic reactions in many people. These are but two examples of problems arising from medically prescribed drugs which are discussed in this article. The danger of taking safe medicines in combinations is explored.

15. Whipple, Dorothy V. and Shultz, Dodi, "Answers to the Most Controversial Questions About Drugs," Today's Health, March 1972, pp. 16-19+.
The author has selected 30 of the questions about drugs most frequently asked by teenagers and parents, and answers them in this article.

16. Zima, Joseph P., and Smith, Gene A., "High School Students, Drugs, and Teachers," School and Society, April 1971.
A report on a study which obtained student reactions to questions about drugs, drug usage, and the role teachers should play in this area.

Questions

You may answer three or more of the following questions to complete this assignment, or you may choose instead to submit a brief written report of your investigation (1-3 pages). The reason so many questions have been included below, is to accomodate the wide variety of approaches available in this lesson.

1. What are some of the problems which may arise from using prescription drugs?

2. Is using marijuana as safe as using alcohol? Is there agreement on the answer to this question?

3. List some of the common narcotic and related drugs. What physiological effects does each produce?

4. Which of the drugs listed in Question Three are addictive?

5. What are the dangers from drug usage other than addiction?

6. What harm may come from using aspirin?

7. How can you select the best brand of aspirin to buy?

8. What organization is responsible for monitering the testing and use of new drugs and medicines? Have they effectively carried out this responsibility?

9. What are some of the problems in testing a new drug or medicine prior to releasing it for use?

10. What are some possible ways to stop the illegal traffic in narcotic drugs? Who do you think should be primarily responsible for stopping this traffic?

INSTRUCTIONAL OBJECTIVES

The Instructional Objectives included with each of the thirteen lessons of the Auto-Instructional course were preceded by the following statement:

Following the completion of Lesson (1 to 13) you should be able to:

Lesson 1

A. Distinguish between observations and inferences.
B. Define scientific law, theory, and hypothesis.
C. Distinguish between laws and theories.
D. Explain or recognize an explanation of the relationship between a theory and a model.
E. Identify those human attributes a scientist should exhibit in his work.
F. Choose from among several examples the one which best illustrates the usual outline of scientific method.
G. Formulate an argument for why "scientific method", as it has often been presented as a hard and fast procedure, is coming under attack.
H. Draw a distinction between science and technology.
I. Discuss the standards by which you believe we can determine how much of our national effort should go to basic science as opposed to technology.

Lesson 2

A. Define, in modern terms, or recognize definitions of the terms element and atom.
B. Draw a distinction between the ancient Greek speculation about what constitutes an element and the modern view.
C. Compare the relationship of science and technology in the alchemical period.
D. Identify the approximate historical period when scientists began thinking of elements in a similar fashion to the modern view.
E. Correctly match famous scientists with their contributions to our knowledge of elements and atoms.
F. Cite at least two values of the Periodic table.
G. Cite at least one example of how the discovery of an element hinged on the discovery of appropriate techniques or instruments.
H. Demonstrate a minimum proficiency in the knowledge of atomic structure as evidenced by your ability to:
    1. Match the primary subatomic particles (proton, neutron, electron) with their properties.
    2. Match the following terms with their proper descriptions: ion, atomic number, mass number, alpha particle, isotope.

3. Identify the element, the number of protons, and the number of neutrons when given the atomic number and mass number of an isotope, or identify the atomic number and mass number when given the element and number of neutrons.

I. Demonstrate a proficiency in the use of the basic metric units of mass and length (as given in Appendix B of the text and used in Experiment 2.1).

Lesson 3

A. Contrast the phlogiston theory explanation with the modern explanation for simple oxidation reactions.
B. Choose those reactions which are exothermic from a descriptive list of simple reactions.
C. Devise or recognize a simple method to confirm the law of conservation of mass.
D. Display a knowledge of the role of oxygen in combustion and respiration by the following:
   1. Recognize the common products of combustion and respiration.
   2. Predict the products of combustion for fuels burning in various circumstances (in abundant oxygen, limited air, etc.).
   3. Recognize examples of reactions in which the oxidation process is useful.
   4. Recognize reactions in which oxidation is undesirable.
   5. Compare the processes of combustion, slow oxidation, and respiration.
E. Exhibit a fundamental knowledge of chemical equations, as evidenced by your ability to:
   1. Provide the proper coefficients to correctly balance simple equations.
   2. Interpret simple equations (including reading them in word form).
F. Describe, by example, how an imperfect theory can serve for a time to explain observed phenomena and can be useful in furthering scientific knowledge.
G. Compare the work of two scientists from your readings for the use of sound scientific inquiry techniques.
H. Discuss the pros and cons of having an imperfect theory that explains the phenomena in logical fashion, or no theory at all.

Lesson 4

A. Correctly match statements of chemical phenomena with the following laws which they illustrate: The law of conservation of mass, the law of definite composition, the law of multiple proportions.
B. State in your own words, or select from a list of statements, the major postulates of Dalton's atomic theory.
C. State in your own words, or select from a list of statements, the corrections which have been made to Dalton's atomic theory.
D. Discuss the pros and cons of having a partially correct theory such as Dalton's.
E. Design an experimentally sound method for confirming the law of conservation of mass.

F. Identify the basis for the present atomic mass scale.
G. Solve simple problems involving atomic masses and mass ratios as illustrated by questions 3, 4, and 5 on page 97 of the text.
H. State or recognize several factors which tend to favor major discoveries being made by particular scientists.

Lesson 5

A. Display a knowledge of Gay-Lussac's Law of Combining Volumes of Gases by the following:
   1. State and illustrate the law by example.
   2. Solve simple problems with volume ratios as illustrated by question number 4.
   3. Recognize the conditions under which the law applies.
B. Display a knowledge of Avogadro's Theory as evidenced by your ability to:
   1. Solve simple problems involving volume ratios and molecular formulas as illustrated by questions 2 and 3.
   2. Use Avogadro's Theory to explain reactions involving simple whole number ratios of gas volumes (question 1).
   3. Use Avogadro's Theory to find molecular masses as illustrated in question 5.
C. Discuss the factors which might explain the reluctance of nineteenth century chemists to accept Avogadro's Theory.

Lesson 6

A. Evaluate the two heat theories presented on the basis of the available evidence, and determine if either one is more acceptable than the other.
B. Explain or interpret common phenomena (such as the increase of tire pressure following driving at highway speeds, the inflation of a balloon on adding gas, the odor of a factory across a city, etc.) by using the appropriate postulates of either heat theory.
C. Cite or recognize those items of experimental evidence that may allow you to prefer one heat theory over the other.
D. Predict what will happen when one or more of the variables (volume, pressure, temperature) are changed in a given situation.
E. Explain how the postulates of the kinetic molecular theory can explain Boyles and Charles Laws.
F. Solve problems involving Boyles and Charles laws as illustrated by questions 12 and 13 following this lesson.
G. Solve problems involving heat and temperature as illustrated by questions 10 and 11 following this lesson.

Lesson 7

A. Describe or recognize the relationship between the following terms:
   1. atomic mass, gram atomic mass, and mole.
   2. molecular mass, gram molecular mass, and mole.
   3. number of particles (atoms, molecules, etc.) and moles.

B. Make the following types of conversions for chemical substances:
   1. grams to moles; moles to grams.
   2. atoms (or molecules) to moles; moles to atoms (or molecules).
   3. liters to moles; moles to liters (for gases at S. T. P.).

C. Solve problems involving balanced chemical equations which involves masses, number of moles, and volumes (for gases) as illustrated by questions 8-10.

Lesson 8

A. Apply to specific instances your knowledge of the relationship between wave length, frequency, and velocity of waves.
B. Apply to specific instances your knowledge of the relationship between color and wave length (or frequency).
C. Apply to specific instances your knowledge of the relationship between the wave length of a radiation and the energy it represents.
D. Illustrate the relationship between the bright line spectra of an element and the Bohr model atom of that element.
E. Demonstrate a knowledge of the Bohr model atom as evidenced by your ability to:
   1. determine the maximum number of electrons for the first four or five energy levels.
   2. determine the number of electrons in each energy level for elements 1-18.
   3. determine the number of outer energy level (valence shell) electrons for any A group element by its position on the periodic chart.

Lesson 9

A. Compare the Bohr model and wave model of the atom.
B. Identify the following: Energy level; sublevel or subshell and orbital.
C. Recognize or draw the shapes of s and p orbitals.
D. Recognize the maximum number of electrons for:
   1. the first four energy levels.
   2. s and p orbitals.
   3. s and p subshells.
   4. outer energy levels.
E. Write electron notations or prepare energy level diagrams for elements 1-10.
F. Identify the number of outer shell electrons as well as the number of electrons in the s and p subshells for any element in the A groups.

Lesson 10

A. Discuss the differences in ionic and covalent bonding.
B. Predict whether ionic or covalent bonding will occur for given pairs of elements.
C. Account for the attractive force in ionic compounds.
D. Recognize the distinguishing properties of ionic and covalent compounds.

E. Account for the fact that water is a liquid, while most other covalent compounds of comparable molecular mass are gases at ordinary temperatures.
F. Draw electron dot structures for:
   1. neutral atoms.
   2. ions.
   3. simple molecules.
G. Account for the regularity evidenced by crystalline solids.

Lesson 11

A. Distinguish between organic and inorganic chemistry, both in the modern and the original sense.
B. Compare organic and inorganic substances as to properties, origin, and response to heating.
C. Draw the possible structural formulas for simple hydrocarbons when given the molecular formula; recognize the structural formulas which are isomeric with one that is given.
D. Predict which of two or more compounds will have the most isomers when given their molecular formulas.
E. State or recognize the way in which octane ratings are made for gasolines.
F. Predict which of two or more compounds will have the highest octane number when given their structural formulas.
G. Recognize those features most desirable in compounds included in gasoline.
H. Make generalizations concerning the relationship between structure and properties, when given data similar to that given on the table in reading 4.
I. Explain or recognize an explanation of the "vital force" theory; suggest a reason for its falling into disfavor.
J. State or recognize the contributions made to organic chemistry by Kekule; discuss or recognize the significance placed on the work of his predecessors by Kekule.
K. Discuss or recognize similarities in structure or properties of compounds isolated from coal tar; contrast these with the type of compounds usually isolated from petroleum.
L. Recognize members of the alkane series from their molecular or structural formulas.

Lesson 12

A. List or select from a given list several natural polymers.
B. Explain or recognize an explanation for the fact that polymer chemistry was not important prior to the twentieth century.
C. Demonstrate a knowledge of the two basic types of polymerization (addition and condensation) as evidenced by your ability to
   1. give or recognize an example of each.
   2. recognize suitable monomers for each type of polymerization by their structural features.
   3. recognize the monomer when given the structure of a polymer; predict the structure of the polymer when given the structure of the monomer (for addition polymerization).

D. State or recognize the principal sources of raw materials for producing polymers.
E. Recognize the principal uses of synthetic polymers.
F. Discuss the question of whether private industry should support basic research as opposed to developmental research.
G. Discuss the general intelligence and personality traits of scientists in comparison with people in other occupational groups.
H. Discuss the impact of new discoveries on established industries, countries, and on the course of history.
I. Discuss the importance of the "accidental discovery" in the history of science.
J. Present an argument for why the general public should have some understanding of the roles played by basic science and technology.

Lesson 13

A. Recognize the structural features common to soap and detergent molecules and describe how the cleansing action is based on these structural features.
B. Recognize the natural substances which are used to produce soap and the method of preparation.
C. Describe what is meant by hard water and recognize the ions responsible.
D. Describe how water softeners work.
E. List or recognize the three basic classes of substances found in commercial laundry preparations and give examples.
F. Recognize why detergents are superior to soap.
G. Discuss the entrophication problem including what it is, the danger to the environment, and the nutrients which may be responsible.
H. Recognize some possible solutions to the phosphate problem as well as the disadvantages of each.
I. Discuss the role which should be played by each of the following in combatting a problem such as the phosphate problem: Government, industry, the public, scientists.
J. Discuss the implications of a sudden and total ban on the sale of detergents containing any phosphates.
K. Discuss the question "Is science good or evil", using examples from your readings in this or previous lessons.

APPENDIX B

STUDENT FEEDBACK INSTRUMENTS

Student Log Sheet: Lesson 1

Student Response Sheet

Course Appraisal

STUDENT LOG SHEET

Lesson 1, Unit I Name_____

Core Activity	Completed	Comment
Reading 1 (Kieffer)		
Reading 2 (Bronowski) (Kieffer)		
Written Exercise 1 (lesson guide)		
Written Exercise 2		
Lab 1.1 (Burning)		
Lab 1.2 (Alka-seltzer)		
Lab 1.3 (Black Box)		

Optional Activity (identify)	Completed	Comment

(fill in date)
Mon____ Tues____ Wed____ Thurs____ Fri____

Time started

Time finished

Mon____ Tues____ Wed____ Thurs____ Fri____

Time started

Time finished

Total Time_____

Student Response Sheet

Name_____

Unit_____

Lesson_____

The answers you provide to the following questions will be used to improve the lesson materials. The few minutes you devote to providing honest responses will be appreciated. Feel free to make comments or suggestions in your own words.

1. Instructional Objectives: The instructional objectives are easy to read and clearly indicate the desired outcomes of the lesson.

____strongly agree ____agree ____disagree ____strongly disagree

2. Lesson Materials

a. The lesson materials are appropriate for reaching the competencies stated in the instructional objectives.

____strongly agree ____agree ____disagree ____strongly disagree

b. The instructional materials accompanying this lesson are

____far too difficult ____too difficult ____about right

____too easy ____far too easy

c. The materials in this lesson are

____very interesting ____somewhat interesting ____average

____somewhat boring ____very boring

d. List any materials you found particularly interesting. Why?

e. List any materials you would omit from this lesson. Why?

f. List any materials from this lesson which should be improved. Why?

g. Other suggestions?

COURSE APPRAISAL

AUTO-INSTRUCTIONAL PHYSICAL SCIENCE

You are requested to answer all questions that you feel qualified to answer. The information from these questionnaires will be used to improve the course for future use. Do NOT sign your name. Please answer the questions in an honest and candid manner.

Circle response

5 4 3 2 1 1. Do you feel that the topics included in this course were appropriate for someone in the elementary education curriculum? (5 very appropriate --- 1 not very appropriate)

What topics would you suggest adding?

What topics would you suggest omitting?

5 4 3 2 1 2. Do you feel that the instructional objectives clearly indicated the desired outcomes of the lessons? (5 very well --- 3 average --- 1 not very well)

5 4 3 2 1 3. Were the lesson materials appropriate for reaching the competencies stated in the instructional objectives? (5 very appropriate --- 1 not very appropriate)

5 4 3 2 1 4. Were the test items fairly constructed and representative of the instructional objectives? (5 very fair and representative --- 3 average --- 1 not very fair or representative)

5 4 3 2 1 5. Do you feel that you learned more in this individualized course than you would have in studying the same topics in a conventional course? (5 a good deal more --- 3 about the same --- 1 a good deal less)

5 4 3 2 1 6. Was the practice of meeting once a week appropriate? (5 very appropriate --- 1 not very appropriate)

Would you suggest meeting more often? less often?

5 4 3 2 1 7. How would you rate the value of optional lesson topics in comparison with the core topics? (5 optional topics better --- 3 about the same --- 1 core topics better)

yes no 8. Would you like to see fewer core topics and more optional topics included in the course?

9. If you answered yes to number 8, what other optional topics would you suggest?

Consider the following types of instructional materials used in the course:

readings (text and other books)	film strips
readings (journals, periodicals)	film loops
readings (with lesson guides)	movies
laboratory investigations	written exercises

yes no 10. Would you like to see any of the materials mentioned above used to a greater degree? If yes, which ones? (You may explain, if you wish.)

yes no 11. Would you like to see any of these materials used less or eliminated? If yes, which ones? (You may explain.)

ind. conv. 12. If you had it to do over again, would you take the individualized version of this course or the conventional approach? (You may explain below, if you wish.)

yes no 13. Would you like to see more courses offered on an individualized basis? (You may explain below, if you wish.)

14. If you answered yes to the previous question, in what areas would you like to see individualized courses offered? (general education, professional education, area of concentration, no preference) Underline your response. (You may explain.)

15. What other suggestions would you make to improve this course for future use?

APPENDIX C

TEST INSTRUMENTS

Test On Understanding Science

Survey of Attitudes and Opinions on Science and Scientists

Processes of Scientific Inquiry Inventory

Science Content Test

612500 129

TOUS

TEST ON UNDERSTANDING SCIENCE

Form W

This test was developed in the course of research at the Graduate School of Education, Harvard University, Cambridge, Massachusetts. It is printed by Educational Testing Service, Princeton, N. J., for experimental purposes only. Unauthorized reproduction or use, in whole or in part, prohibited. Copyright 1961, by W. W. Cooley and L. E. Klopfer.

1. The chief purpose of the science of botany is to

   A. teach farmers how to produce more food.
   B. develop new drugs and medicines from plants.
   C. provide explanations on how plants grow and reproduce.
   D. tell us what plants will grow best in various kinds of soils.

2. Among the hundreds of scientific societies in various countries throughout the world, we find that

   A. scientists voluntarily join the societies related to their special field.
   B. national governments generally direct these societies.
   C. membership is generally restricted to scientists of one nation.
   D. national governments are seldom interested in these societies.

3. In the past, many important scientific discoveries were made by men who were clergymen, statesmen, or businessmen, and who worked on science as amateurs. This is no longer true today because

   A. men in other professions are less interested in science today than they used to be.
   B. scientific research today requires many years of preparation, usually study beyond college.
   C. important discoveries cannot be made today without expensive equipment which only scientists possess.
   D. only professional scientists have the abilities needed to make important discoveries.

4. The people and government of a country influence scientific activity

   A. very little, because scientists are quite isolated from the rest of society.
   B. a little, because people must be willing to become scientists and to pay for science.
   C. a great deal, because most scientists work for the government and must follow its instructions.
   D. a great deal, because the education and support given to scientists depend on how the people feel about science.

5. In the 17th century, Newton formulated his laws of motion and the theory of universal gravitation, which were eventually accepted by all physicists. In the 20th century, Einstein proposed a much broader theory of relativity, which physicists have generally accepted. Physicists today consider Newton's ideas as

   A. mistaken notions, because of Newton's limited experience.
   B. part of Einstein's theory, as a special case.
   C. applicable only to physical events in another world.
   D. superior to Einstein's, because they have a longer tradition.

6. An astronomer in Australia reports that he has seen evidence of plant growth on the planet Venus. American astronomers will accept this report as a fact if

   A. other independent observations confirm the report.
   B. the species of the plants have been identified.
   C. the Australian government certifies the observation.
   D. other astronomers agree that there is oxygen on Venus.

7. The microscope came into wide use in scientific work in the 17th century. This new instrument made it possible for scientists to see very small objects, and also to

   A. look more closely at the ultimate nature of matter.
   B. discover the real meaning of life.
   C. look more closely at cause and effect relationships.
   D. explore new problems unknown before this time.

8. The principal function of scientific societies is to

   A. promote the economic welfare of their members.
   B. publish and sell scientific books and periodicals.
   C. promote the exchange of ideas and maintain professional standards.
   D. inform non-scientists of important scientific discoveries.

9. If we compare successful scientists with successful people in most other professions, we find that these

   A. scientists tend to have higher incomes than other professionals.
   B. scientists require more specialized training than other professionals.
   C. scientists and other professionals have set rigid certification laws which keep out those who are not qualified.
   D. scientists and other professionals tend to devote most of their energies to their work.

10. If we ask an astronomer to explain why some stars vary in apparent brightness, he will most likely give his explanation in terms of

   A. the necessity of stars to vary in brightness.
   B. accepted scientific laws and principles.
   C. exact mathematical equations and formulas.
   D. verified astronomical observations and data.

11. Several recent reports have pointed out a tendency in the United States toward increased conformity, thus discouraging creativity. If these reports are correct, we can expect that in the United States

A. scientists will conform to higher standards of accuracy.
B. scientists will work together more productively.
C. creative arts, like music and painting will suffer, but not science.
D. both science and the arts will suffer in the future.

12. The principal aim of science is to

A. verify what has already been discovered about the physical world.
B. explain natural phenomena in terms of principles and theories.
C. discover, collect and classify facts about animate and inanimate nature.
D. provide the people of the world with the means for leading better lives.

13. It has often been said that published reports of scientific research are generally very accurate and honest.

A. This is true because scientists are very accurate and honest people.
B. This is true because only one answer can be correct in science.
C. This is true because reported results can be checked by other scientists.
D. There is little basis for this claim.

14. In 1935 a Japanese physicist, Hideki Yukawa, made an important contribution to the theory of nuclear physics. This occurrence was not considered unusual because

A. nuclear physics is taught in schools throughout the world.
B. almost anyone can contribute a scientific theory.
C. most Asian scientists know a great deal about nuclear physics.
D. people from many countries contribute to science.

15. Of the following, which is the best statement about scientific knowledge?

A. Scientific knowledge is a systematic collection of facts.
B. Data and ideas from the past contribute to today's scientific knowledge.
C. Each generation starts anew to build up its own scientific knowledge.
D. Statements are not accepted as scientific knowledge unless they are absolutely true.

16. Which one of the following statements best describes the most important contribution scientists make to our society?

A. Scientists provide knowledge about natural events.
B. Scientists make improved products for better living.
C. Scientists provide skilled services or advice to others.
D. Scientists show us what we should strive for.

17. Are biology, chemistry, and physics related or are they not? They are

A. not related because they are built on different sets of fundamental principles.
B. related, because the observation, principles, and ideas of each field have connections with the other two.
C. related, because mathematics serves to unify the sciences.
D. not related, because biologists, chemists, and physicists study very different natural phenomena.

18. John Smith is a very imaginative young person. He may never become a scientist because

A. he would not want to give up his freedom of thought.
B. imaginative people usually become artists and writers.
C. he might like some other field better than science.
D. science is too factual for John.

19. If a physicist and a livestock dealer were to walk into an experimental biology laboratory together for the first time, which man would probably understand what was going on there more quickly?

A. Both men would understand at about the same time, because neither of them is a research biologist.
B. The livestock dealer, because the training for his job most likely included the methods of experimental biology.
C. The physicist, because biologists and physicists have similar points of view toward investigating natural phenomena.
D. The physicist, because physicists do the same kind of laboratory work that biologists do.

20. At present, at least 90% of U. S. Government money for research and development pays for such things as ballistic missiles, nuclear reactors, insecticides, vaccines, computers, rocket fuels, and space suits. Many scientists are critical of this allotment of Government money because

A. less than 10% is allotted to technological applications.
B. less than 10% is allotted to research in science.
C. only 90% is allotted to research in science.
D. only 90% is allotted to technological applications.

21. Today, physicists of several countries are working on experiments to determine whether or not one of Einstein's theories correctly predicts the effect of gravity on light. This activity best illustrates the fact that

A. an important function of theories is to stimulate research.
B. it is important to have a precise value for the speed of light.
C. it takes a long time to prove that a theory is really true.
D. theories are still doubted long after they are proven true.

22. Scientists are often described as having certain "scientific attitudes." These may be best observed when scientists are

A. actually engaged in research.
B. asked to work outside their field.
C. doing most anything.
D. with their families and friends.

23. The design of a television receiver is a problem of

A. science, because it calls for ingenuity and originality.
B. science, because the design must be developed by experiment.
C. technology, because it leads to the production of a practical device.
D. technology, because the designer must have technical ability.

24. Today, the education of American scientists who teach and do research at universities generally

A. is completed after four years of college.
B. includes a period of practical training in industry.
C. is completed after five years of college.
D. includes study for advanced degrees after completing college.

In items 25 to 30 you are to choose the answer which is an EXCEPTION or is LEAST LIKELY to belong in the group and blacken the space under the corresponding letter on the answer sheet.

25. Scientific journals have all of the following functions EXCEPT to

A. serve as a forum for the discussion of new theories.
B. provide information on research which is in progress.
C. print papers which were read at scientific meetings.
D. explain policies of scientific societies for the conduct of research.

26. If a botanist wants to determine the factors that contribute to the growth of a certain plant, which of the following things will he be LEAST LIKELY to do?

A. Formulate an hypothesis based on what he thinks the factors are.
B. Write a mathematical equation of the growth curve.
C. Think about the factors that contribute to the growth of other plants.
D. Look the subject up in the library.

27. The American Chemical Society (ACS) is one of the largest scientific societies in the United States. Which of the following functions would the ACS be LEAST LIKELY to carry on?

A. Negotiate contracts with companies employing chemists.
B. Assist its members in finding new jobs.
C. Publish chemical journals and books.
D. Establish standards of terminology in chemistry.

28. Scientists cooperate on an international scale through all of the following activities EXCEPT

A. setting the values of physical constants.
B. publishing scientific journals.
C. prescribing courses for the preparation of scientists.
D. advising United Nations agencies.

29. Which one of the following factors will be the LEAST HELP to the growth of science in America?

A. Setting national goals for discoveries that must be made.
B. Improving the means of communication among scientists.
C. Improving the training of high school science teachers.
D. Reducing security restrictions on scientific knowledge.

30. An example of a scientific model is: "The atom is like a miniature solar system composed of electrons in orbits, and, in the center, a nucleus containing protons and neutrons." Which one of the following statements about scientific models is NOT correct?

A. They are man-made constructs and may not represent reality.
B. They consist of a relatively small number of assumptions.
C. They represent what scientists could see with very powerful instruments.
D. They are tentative and may be modified or discarded.

SPECIAL DIRECTIONS FOR ITEMS 31 TO 37

In each of the following items, there is a statement about scientists on the left and a reason for that statement on the right. On the appropriate numbered line of the answer sheet, blacken the space under

A. if both the statement and the reason are generally true;
B. if the statement is generally true but the reason is false;
C. if the statement is false but the reason is generally true;
D. if both the statement and the reason are false.

Summary of Directions

	STATEMENT	REASON
A.	generally true	generally true
B.	generally true	false
C.	false	generally true
D.	false	false

	STATEMENT		REASON
31.	Two kinds of scientists, experimentalists and theoreticians, are found in most branches of science	BECAUSE	good theoreticians are not trained in the skills needed in laboratory work.
32.	Scientists are less likely than people in other professions to have a normal happy family life	BECAUSE	scientists spend every possible minute in their laboratories.
33.	Work in the various branches of science requires the same abilities and skills	BECAUSE	scientific methods are used in all branches of science.
34.	Scientists are honest and self-critical in their work	BECAUSE	these scientific attitudes are personal characteristics of scientists.
35.	Scientists are generally geniuses	BECAUSE	creative ability is often called for in attacking scientific problems.
36.	Most scientists are dedicated to their work	BECAUSE	scientists have an abnormal desire to succeed in life.
37.	The training of a physicist is just about the same as the training of a chemist	BECAUSE	the different branches of science demand the same kinds of skills in their workers.

38. Betty is planning an experiment to learn something about the role of potassium in the growth of a certain plant. She decides to grow one group of these plants in soil containing nitrogen and phosphorus, but lacking potassium. A second group of these plants, serving as a "control," should be grown in soil containing

A. potassium only.
B. nitrogen, phosphorus, and potassium.
C. nitrogen and potassium, but no phosphorus.
D. nitrogen and phosphorus, but no potassium.

39. Most of the important scientific advances have come about as the result of

A. the development of new and more significant sets of ideas.
B. the interaction of ideas and experiments in the solution of problems.
C. the dedication of an extraordinary man to the investigation of a particular specialty.
D. an interaction between a chance observation of a new phenomenon with an alert mind.

40. A scientific society is

A. a society that is run according to scientific methods.
B. an organization that seeks to make society more scientific.
C. a society in which people believe in the importance of science.
D. an organization of scientists that promotes scientific work.

41. Which one of the following statements best describes the connection between science and technology today?

A. Technology involves the practical applications of scientific knowledge.
B. Science depends on technology for ideas and the organization of experimental work.
C. Workers in science use the laws and principles discovered by workers in technology.
D. Technology is the part of science that deals with mechanical problems.

42. In regard to intelligence, most scientists

A. have about average intelligence.
B. are born with a special scientific aptitude.
C. are smart because of their special training.
D. have more than average intelligence.

43. Which of the following is the best description of a scientific law?

A. It is an exact report of the observations of scientists.
B. It is a generalized statement of relationships among natural phenomena.
C. It is a theoretical explanation of a natural phenomenon.
D. It is enforced by nature and cannot be violated.

44. Which of the following is the principal need of science?

A. much expensive equipment
B. well-trained assistants
C. large sums of money
D. creative individuals

45. When some of the facts in a certain area of science are <u>not</u> explained by an existing theory, scientists

A. may revise the unexplained facts so that they will fit into the theory.
B. may modify the theory so that more of the facts will be explained.
C. should discard the theory and formulate a new one immediately.
D. should show the theory to be in error in all cases.

46. Gay-Lussac carried out many experiments with gases and observed that when heat is applied to gases their volumes always increase, providing the pressure remains the same. Gay-Lussac decided that "at constant pressure, the volume of a gas varied directly with the temperature." This is an example of

A. formulation of a scientific theory.
B. testing of a scientific hypothesis.
C. formulation of a scientific law.
D. reasoning from the abstract to the concrete.

47. Bill always makes good grades in school, but is a practical joker. Frank also makes good grades but has no sense of humor. Janet is a serious, intelligent, and popular girl. Who would most likely become a research scientist?

A. Frank
B. Janet
C. either of the boys
D. any one of the three

48. In deciding whether or not a proposed theory can be accepted, scientists will probably make their decision on the basis of

A. whether or not the theory is true.
B. whether or not the theory can be expressed in mathematical form.
C. the evidence supporting the theory and their personal ideas.
D. the experimental and observational evidence available.

49. Before an astronomer presents a new theory, he will generally get criticism of his ideas from

A. his co-workers in astronomy.
B. a panel of experts on astronomical theories.
C. a theoretical physicist.
D. a philosopher who has studied the development of theories.

50. Ralph said: "Scientists do experiments to ask questions of nature." The best interpretation of Ralph's statement is that experiments and tests are used in science to

A. prove the regularity of nature.
B. learn by trial and error.
C. check predictions made from scientists' observations and ideas.
D. inquire into the mystery of creation.

51. Standing on a hilltop at dawn, two men were observing the eastern horizon. One said, "In a few minutes, the sun will rise above the horizon and travel up into the sky." The other said, "In a few minutes the earth will be turning into a position that will allow us to see the sun above the horizon." What aspect of observations in science is illustrated by this story?

A. Special instruments are needed to make accurate observations.
B. Good observations are objective and free from bias.
C. Observations are relative to the position of the observer.
D. Many apparently objective observations are interpretations of what is seen.

52. If we were to check on the contributions to science that have been made in various countries since 1900, we would expect to find representation chiefly from

A. the United States and Russia.
B. England and France.
C. the four countries listed in A and B.
D. the countries listed and others.

53. Manufacturers of scientific instruments are continually adding new models to their lines because

A. the older instruments are no longer reliable.
B. the old instruments go out of style, like automobiles.
C. improved instruments are needed as science advances.
D. new science laboratories require the latest equipment.

54. In carrying out biochemical research, the methods used by the investigator generally include

A. any method that is approved by the Biochemical Society.
B. any method he can think of to help solve his problem.
C. the method of trial and error experimentation.
D. only biochemical methods which are known to yield results.

55. After Volta devised an electric battery in 1800, a period of rapid progress in the sciences of electricity and chemistry soon followed, because this new instrument

A. made it possible to have well-lighted laboratories.
B. made possible a new industry to manufacture batteries for general use.
C. contained the answer to several electrical and chemical problems.
D. made possible many new experiments and observations.

56. If a geologist is attempting to establish a theory about the origin of mountains, he would

A. rule out all previous attempts to explain mountain-building.
B. correlate all his evidence with geologic maps.
C. see if it explains the known data on mountain-building.
D. study the geological record of all mountains in the United States.

57. When a scientist has established a theory, we may say that he has

A. developed new ideas and understandings.
B. uncovered one of the laws of nature.
C. moved mankind closer to knowledge of absolute truth.
D. discovered new experimental evidence.

58. Mary is interested in science but does not like the way her chemistry teacher makes her write down all the details of her experiments. However, this training will help Mary if she goes into science, because she will have learned how to

A. look for cause and effect relationships.
B. be patient.
C. make more accurate reports.
D. deduce theories from experiments.

59. If you were browsing through the periodicals section of a physics research library, you would notice that almost all the scientific journals

A. are written in English, German, or Russian.
B. report current work in a highly technical style.
C. carry many advertisements of new products.
D. explain the latest physical discoveries for the layman.

GO ON TO THE NEXT PAGE

60. In discussing our country's disarmament policy, a famous scientist declared that we must continue our experimenting with nuclear bombs. What is the best evaluation we can give to this scientist's statement?

A. His conclusion is probably right, since he approaches the problem with a scientific attitude.
B. His conclusion is probably wrong, because scientists seem to be trying to destroy the world.
C. His conclusion and reasons are probably correct, because scientific results are the most reliable kind.
D. His conclusion and reasons should be weighed according to his knowledge of international affairs.

DIRECTIONS

This is a test of your general knowledge about science, scientists, and the ways in which scientists do their work.

Each of the questions in this test is followed by four suggested answers. You are to decide which one of these you think is the BEST answer to the question. Then mark the proper space on the answer sheet with the special pencil you have been given. Make the mark as long as the pair of lines, and move the pencil point up and down firmly to make a heavy black line. If you change your mind about an answer, erase your first mark completely. Mark only one answer for each question.

Example:

XX. The main thing that a scientist does is to

A. collect scientific books.
B. build laboratory equipment.
C. give lectures about science.
D. carry on scientific research.

Notice that in this example several of the choices are at least partly correct but choice D is clearly the BEST answer, because carrying on scientific research is the "main thing" that a scientist does. In many of the questions of this test you may find several choices which are partly correct, so that you will have to decide which one is the BEST answer. Be sure that you mark only one answer for each question on the separate answer sheet.

You will make your best score by answering every question. You should work carefully, but do not spend too much time on any one item. If a question seems too difficult, make the most careful guess you can. If you finish before time is called, go back and spend more time on the questions about which you were doubtful.

Please do not mark this test booklet in any way.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Item No. 612500

SAOSS
Form CGv

A S U R V E Y

Directions

This is a survey of your attitudes and opinions on a variety of topics concerning science and scientists.

Each item consists of two alternatives, A and B, between which you are asked to choose by circling one of these indicators:

A = Statement A is entirely preferred to Statement B as an expression of my opinion.

a = Statement A is somewhat preferred over Statement B.

? = I cannot choose between A and B.

b = Statement B is somewhat preferred to Statement A.

B = Statement B is entirely preferred to Statement A as an expression of my opinion.

Please try to show your attitude leanings on each item, even though you do not feel strongly on the topic or do not feel well informed. Choose between the alternatives, if possible, even though both may seem acceptable to you, or both unacceptable.

Please mark your answers on the separate answer sheet, not in this booklet.

1. A. New scientific discoveries and ideas are of very little interest to me personally.
   B. I'd like to keep informed about new discoveries and ideas in science.

2. A. Doing experiments and other science activities is something that's suitable mostly for boys.
   B. Girls can enjoy doing experiments and other science activities just about the same as boys.

3. A. To become an informed citizen, every young person today should study science in the elementary and secondary schools.
   B. The average person actually needs to know very little science in order to live a successful life.

4. A. Most people do not sufficiently appreciate the importance of science.
   B. The importance of science for our society is generally overrated by the public.

5. A. With so many other choices available, it doesn't make much sense to take any more science courses in college than the required minimum.
   B. If I can fit it into my schedule, I'd like to take some more science courses in college.

6. A. Both female and male teachers are equally capable of teaching science in the elementary school.
   B. Wherever possible, science should be taught in elementary schools by a man.

7. A. Developing the skills of all elementary school children in scientific inquiry is at least as important as helping them learn social studies and mathematics.
   B. While children should learn some science in the elementary school, much more time should be spent on social studies and mathematics.

8. A. The benefits of science clearly outweigh any harm that has come from science.
   B. On balance, science and its inventions have caused more harm than good.

9. A. My everyday experiences are made more meaningful through an understanding of science.
   B. Science is very minimally related to my experiences in everyday life.

10. A. The demands of science as a profession make it particularly suitable for someone with the strong personal characteristics which males usually have.
    B. Women are no less or no more qualified than men to become scientists in terms of the intellectual and physical demands of the profession.

11. A. The National Science Foundation should be allocated whatever funds it reasonably requests from the U.S. Congress.
    B. If the U.S. Congress were really wise, it would allocate much more money to the National Humanities Foundation than to the National Science Foundation.

12. A. The boundaries of scientific research should be limited only by man's imagination.
    B. It would be well to put some reasonable limits on scientific research to prevent its unwholesome expansion.

13. A. When a science program is on television, I usually tune to another channel.
    B. I usually try to take the time to watch a good science program on television.

14. A. A scientist is just as likely to possess the necessary skills for holding public office as a lawyer or a businessman.
    B. Other factors being equal, I would vote for a lawyer or a businessman who is running for public office against a scientist.

15. A. We should limit the amount of money spent on scientific research because the scientific discoveries of the twentieth century have led to more problems than solutions.
    B. We are not spending too much money on scientific research, because the solution to many of today's problems may eventually come from that research.

16. A. Science, by constantly improving man's life, has created social problems which outweigh the value of the scientific advances themselves.
    B. Even if the advance of science has created some social problems, the gains in knowledge and understanding have been worth it.

17. A. There are quite a few things in science that I wish I had some time to find out about.
    B. Whatever spare time I have, it's not worth it to me to use it on anything connected with science.

18. A. I would try to persuade my brother not to become a scientist even if he had the talent for it.
    B. If my brother had the aptitude needed for becoming a scientist, I would urge him to try to be one.

19. A. The nation's taxpayers ought to be alarmed about the huge sums of money the federal government is ploughing into scientific research.
    B. Most of the taxpayers' money that the federal government puts into scientific research may be a worthwhile investment for the nation's future.

20. A. Science, along with other fields of inquiry, can lead the way to a better future world.
    B. If the world is to have any future at all, we must give up our over-reliance on scientific inquiry.

21. A. I can hardly wait to try out some interesting science activities with a group of children.
    B. If I never get involved in science activities with children, I wouldn't mind it at all.

22. A. I'd like to have friends who are scientists.
    B. I don't think I'd be too happy about having scientists as my friends.

23. A. Advances in science really won't have any significant effects on the future of mankind.
    B. The future of mankind depends in large part on the advances of science.

24. A. The prospect of having to teach science regularly to elementary school children literally frightens me.
    B. I feel as comfortable about the prospect of teaching science to elementary school children as I feel about the prospect of teaching reading, arithmetic, and social studies.

25. A. Scientists are particularly biased about public affairs because they have to push for their own special interests.
    B. Scientists are about as objective and rational about public issues as the average citizen.

26. A. All things considered, we would be better off if science weren't so prominent today.
    B. There's really little need for anxiety about the prominence of science in today's world.

27. A. It would be as enjoyable for me to help an elementary school child learn how to make and record observations in science, as to help him learn to read a sentence or add numbers.
    B. Helping a child to discover the meanings of new words or how to spell them would be more rewarding to me than helping him learn about observing natural events and science experiments.

28. A. In this day and age in which we live, learning about science is at least as important as other subjects.
    B. Science is interesting, but it isn't as important to learn about as most other subjects.

29. A. I'm more likely to gain new interests and ideas from studying other subjects than from studying science.
    B. Studying science is valuable to me because it opens the way to exciting new interests and ideas.

30. A. Generally speaking, scientists aren't any more trustworthy than used car salesmen.
    B. Scientists can be trusted approximately as much or as little as most other people.

31. A. Getting married to someone who is a scientist would probably be about as satisfying as marrying anyone else.
    B. Given the choice, I certainly wouldn't get married to someone who is a scientist.

Processes of Scientific Inquiry Inventory

Do not write on test booklet: use the answer sheet provided.

1. An opaque drinking glass is resting on a table at the front of the classroom. From your seat in the second row, you observe what appears to be droplets on the glass. Which of the following sentences gives the best observation you could make without leaving your seat?

   (A) The metal glass contains an ice-water mixture because there is condensation on the glass.
   (B) The metal glass contains some cold material because condensation is observed on the glass.
   (C) There is something on the outside of the glass which gives the appearance of being moisture.
   (D) There is condensation on the outside of the glass.

2. Imagine that you have a sealed cardbord box to examine. On tipping and shaking the box it becomes apparent that there is only one item in the box which rolls smoothly in one direction and slides in the other direction. An externally placed magnet can affect the rolling and sliding action. The best statement you could make regarding the object would be

   (A) The object is spherical and composed of a magnetic materical.
   (B) The object is a solid stainless steel cylinder.
   (C) The object is cylindrical in shape and composed of a magnetic material.
   (D) The object is a hollow, metallic cylinder.

3. Another student repeats the investigation using a different box and magnet. The results are identical except that the magnetic effect is noticeably less. You could correctly say that

   (A) The object in your box is larger than the object in the other student's box.
   (B) The object in your box is smaller than the object in the other student's box.
   (C) Your magnet is stronger than the other student's.
   (D) More information is needed to reach a conclusion.

4. Suppose that you strike a match, cup it in your hands, and light a cigarette for a fellow student. (he hasn't heard that smoking is harmful). Which of the following statements is not an observation?

   (A) There is oxygen in the air around the match.
   (B) Heat is given off by the burning match.
   (C) The burning match gives off light.
   (D) One of the products resulting from the burning of the match is a black substance.

5. A quantity of metal is dropped into a liquid in an open flask. You can observe no gas being emitted but suspect that a gas may be formed at such a slow rate that it is not being detected. Which of the following measurements, taken at two different time intervals, would be most useful to you?

(A) The mass of the flask and contents.
(B) The temperature of the flask and contents.
(C) The pressure in the flask and the temperature of the air.
(D) The pH of the contents of the flask and the mass of the flask.

6. What would you measure to determine if the rate of molecular motion of a gas contained in a steel cylinder, had changed?

(A) mass
(B) temperature
(C) volume
(D) density

7. Which piece of equipment would be used for measuring mass?

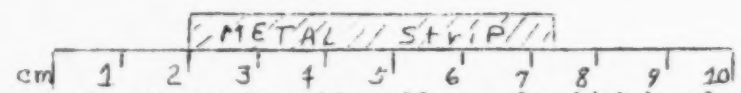
(A) graduated cylinder
(B) meter stick
(C) thermometer
(D) triple beam balance
(E) spring scale

8. Which instrument would you use to measure the wave length of radiation emitted when electricity is passed through a tube filled with helium gas?

(A) an analytical balance
(B) an optical spectroscope
(C) a meter stick
(D) a vernier caliper
(E) a mass spectroscope

9. Which of the following instruments would be most helpful in indentifying the masses of isotopes?

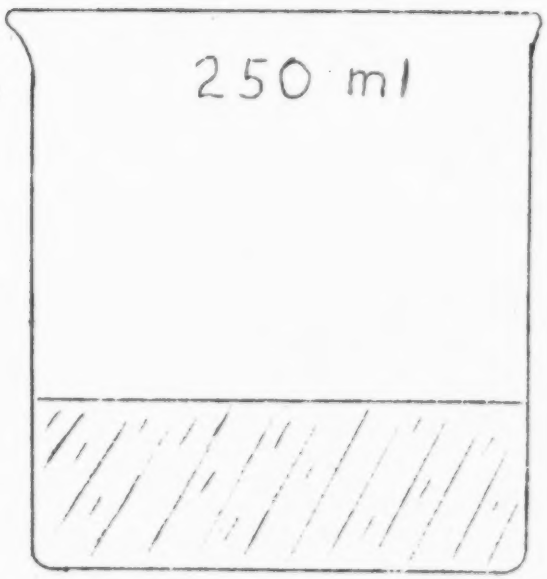
(A) a mass spectroscope
(B) an electron microscope
(C) a triple beam balance
(D) a precision analytical balance
(E) an optical spectroscope



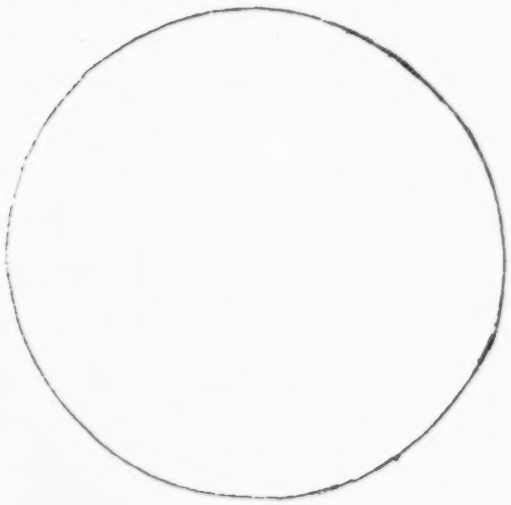
10. A metal strip is placed alongside a 10 cm rule which has 1 cm between the smallest markings on the scale. (shown above) Which of the following reported measurements shows that the best use was made of the instrument?

(A) 5 cm
(B) 5.3 cm
(C) 5.36 cm
(D) 7.3 cm
(E) 7.5 cm

Side View



Bottom View



11. Shown above is a side view of a 250 ml laboratory beaker drawn approximately to actual size. The amount of liquid shown in the beaker would best be estimated as

(A) 10 ml
(B) 40 ml
(C) 90 ml
(D) 150 ml
(E) 180 ml

12. A small piece of metallic appearing material is dropped into a clear liquid in a flask. After a period of time, bubbles form on the metal, escape, and rise to the surface. Which of the following statements represents the best <u>observation</u> you could report?

(A) Bubbles of a gas are being formed, possibly due to a chemical change and being released.
(B) No chemical change is occuring, because no color change is noticed in the liquid.
(C) Air, trapped in the pores of the metallic material, is bubbling out.
(D) Bubbles of a gas are forming, proving that a chemical change is taking place.

The table below gives approximate melting points of some ionic compounds, as well as the radius of the positive ion (cation) and negative ion (anion). Answer questions 13 and 14 using the table.

	Cation radius (angstroms)	Anion (-ion) radius (angstroms)	Melting point
Na^+Cl^-	.95	1.81	801°C
Na^+Br^-	.95	1.95	755°C
Na^+I^-	.95	2.19	651°C
K^+Cl^-	1.33	1.81	776°C

13. Which of the following statements is the best interpretation of the data in the above table?

(A) As the anion becomes larger, the melting point of an ionic compound increases.
(B) As the anion becomes larger, the melting point of an ionic compound decreases.
(C) As the cation becomes larger, the melting point of an ionic compound increases.
(D) As either the cation or the anion becomes larger, the melting point of an ionic compound decrases.
(E) Not enough information is given to select any of the answers above.

14. Suppose that samples of each of these compounds are heated in an oven to a temperature of 790°. If the temperature of the oven is then lowered, which of the samples would solidify first?

(A) Na^+Cl^-
(B) Na^+Br^-
(C) Na^+I^-
(D) K^+Cl^-

15. You are given containers holding the following substances, all at room temperature:

(1) 28 grams of gas x
(2) 32 grams of liquid y
(3) 40 grams of solid z

Which of the following statements is correct?

(A) There are more molecules in container (3) than in either of the other two containers.
(B) There are more molecules in container (2) than in either of the other two containers.
(C) There must be a different number of molecules in each of the containers.
(D) There are more molecules in container (1) than in either of the other two.
(E) There is not enough information given to compare the number of molecules in the containers.

The following table lists the results of a hardness test performed to determine if you should buy a water softening unit for your home:

	sample	number of drops of soap to produce permanent lather
I.	distilled water	10
II.	hard water (distilled water with a calcium compound added)	60
III.	treated water (solution II with a chemical "softener" added)	20
IV.	tap water (untreated	45
V.	tap water (treated with the same amount of chemical "softener" used in sample III)	15

16. Should you buy the water softening unit?

(A) No, because the lather producing ability of distilled water couldn't be achieved anyway.
(B) No, because your tap water is not as hard as the prepared "hard water."
(C) Yes, because a significant reduction in hardness can be achieved.
(D) The results of the test are not conclusive enough to reach a decision.

17. A student decided to test the hypothesis that a particular metal does not react with acids. He placed a sample of the metal in ten different acids. No reaction occurred in any of the tests.

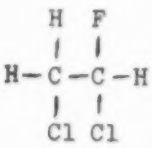
Conclusion: The metal does not react with acids.

Choose one the following statements which best evaluates the conclusion.

(A) The conclusion does not agree with the data of the experiment.
(B) The conclusion agrees with the data and is acceptable.
(C) The conclusion does not agree with commonly accepted chemical laws.
(D) The conclusion may be tentatively accepted.

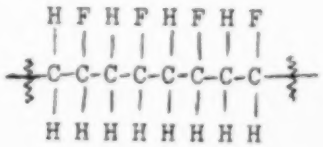
The following properties of an organic compound were experimentally determined:

I. The compound reacted with chlorine to produce



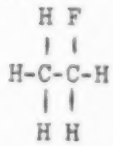
with no other product.

II. The compound underwent polymerization to yeild a long chain polymer with the structure

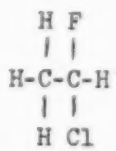


18. Five structures of the compound are hypothesized below. On the basis of the above information, which is the most likely structural formula of the compound?

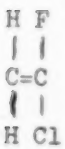
(A)



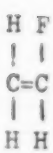
(B)



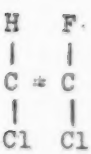
(C)



(D)



(E)



John Dalton proposed his atomic theory in the early 1800's. He viewed atoms as indivisible particles that combine in small whole number ratios in forming compounds. He proposed that each element was composed of identical atoms, and that different elements had atoms which were different.

The modern atomic theory recognizes that all atoms of a given element behave the same in chemical reactions, but may differ in mass. It recognizes that atoms are divisible into smaller particles and that an atom's identity may be changed by a nuclear reaction.

Items (19) to (23) are observations of phenomena involving atoms. Choose one of the statements, (A)-(D) which best satisfies each of the items.

(A) the observation supports or can best be explained by Dalton's atomic theory
(B) the observation supports or can best be explained by modern atomic theory.
(C) the observation can be explained equally well by either theory.
(D) the observation cannot be explained by either theory.

19. The formula for water is always H_2O, while the formula for zinc chloride is always $ZnCl_2$.

20. When bombarded with alpha particles, beryllium is converted to carbon-12 plus neutrons.

21. Regardless of the source of sulfur, sulfur atoms will combine with oxygen from the air to produce sulfur dioxide.

22. Other conditions being identical, water always evaporates faster on a warm day, than a cool day.

23. Chlorine atoms always gain one electron each in becoming chloride ions.

24. A Scientific Theory should
(A) suggest procedure to use for carrying out experiments.
(B) tie together and help to explain many natural phenomena.
(C) contain nothing but proven scientific facts.
(D) supply directions for preparing useful things.
(E) supply the final answer to questions of a scientific nature.

25. Which of the following measurements can be applied in the greatest number of cases in determining the rate of a chemical reaction?
(A) the rate at which the temperature of the system changes
(B) the amount of product formed in a given time
(C) the rate at which the pressure changes
(D) the change in the color of the system

26. A 10 ml graduated cylinder has a scale which has 0.1 milliliters between the smallest divisions. Which of the following reported measurements made the best and most efficient use of the instrument?
(A) 8 ml (B) 8.1 ml
(C) 8.12 ml (D) 8.124 ml

For items 27 through 30 consider the following theories in explanation of the burning of material in air:

Theory X. During combustion a substance escapes from the burning material into the surrounding air. The capacity of air to take up this escaping substance is limited.

Theory Y. During combustion, the burning material unites with a certain component of the air.

After the number on the answer sheet corresponding to each of the following items, place one of the following answers:

(A) if the item supports Theory X rather than Theory Y
(B) if the item supports Theory Y rather than Theory X
(C) if the item supports both theories equally well
(D) if the item, taken by itself, does not support either theory

Assume you know no facts other than those given in the numbered items below.

27. A candle in a closed jar stops burning before the candle is completely burned.

28. Air contains approximately 20 per cent oxygen.

29. The product formed by burning iron in air weighs more than the original iron.

30. A candle burns more brightly in a breeze than in still air.

31. Suppose that you prepare three samples of a compound of sulfur and oxygen. The first time you combined 2.0 g of sulfur with 3.0 g of oxygen. The mass of compound produced was 5.0 g. In the second trial 1.0 g of sulfur combined with 1.5 g of oxygen to produce 2.5 g of compound. In the last trial 7.5 g of compound was produced from 3.0 g of sulfur and 4.5 of oxygen. Prepare a data table in the space provided to include these data. Add to the table any calculations you may need to make to determine if the given data are in accord with the law of definite composition. If they are, place a "yes" in the blank provided; if not, place a "no" in the blank.

32. A student was given the task of finding the average mass of metal pellets. He first determined the mass of 5 separately and found their masses in grams to be .17, .18, .18, .17, .16. He then determined the mass of 120 pellets and found it to be 22.20 grams. What should he report for the average mass of a pellet? (Show your work and place answer in the blank provided.)

33. A student is asked to determine the percentage (by mass) of oxygen in a sample of potassium chlorate. He plans to heat the sample in a test tube to drive out the oxygen. Which of the following entries is <u>not</u> needed in his data table?

(A) Mass of test tube and sample before heating.
(B) Mass of test tube.
(C) Mass of test tube and sample after heating.
(D) Mass of sample after heating.
(E) Loss of mass on heating.

Name:

Number:

_____1. Which of the following is the best statement regarding the distinction between observations and inferences?

A. Observations are made with the eyes; inferences involve the other senses.
B. An observation is recognizing and noting an event or occurence, while an inference is like a guess.
C. Observations are made with the senses; inferences involve the use of measuring instruments.
D. You must be near something to observe it; inferences can be made at long range.

2. The following is a list of statements a student placed in her notebook after dropping an alka-seltzer in water (lesson 1). (No measuring instruments were used) Place an O beside those statements she placed on her list of observations; place an I beside those placed on her list of inferences.

____(1) The water temperature increased.

____(2) Bubbles were produced.

____(3) Carbon dioxide was produced.

____(4) A chemical change occurred.

3. From the statements in the right hand column select the one which best identifies the terms in the left hand column.

____ (1) scientific law

____ (2) theory

____ (3) hypothesis

____ (4) element

____ (5) atom

A. a tentative assumption made in order to test its consequences.

B. a statement about the consistency nature displays.

C. a collection of postulates or assumptions concerning a portion of the natural world.

D. a binding rule which substances invariably obey.

E. a group of statements about a portion of the natural world which are known facts.

F. the smallest structural unit of a compound.

G. a sample of matter in which all atoms have an identical number of protons and electrons.

H. a sample of matter in which all atoms have an identical no. of protons, neutrons, & electrons.

I. the smallest structural unit of an element.

____4. One explanation of the nature of light is that light is composed of photons or packets of energy. The energy of a photon is the difference between two stationary energy states in an atom or molecule. When a beam of these photons strikes a metal, the photons give their energy to electrons in the metal. This creates a tendency for the electrons to be ejected (photoelectric effect). Which of the following is the best statement?

A. The statements above constitute a theory of light.
B. the statements above are a collection of scientific laws concerning light.
C. The statements above are hypothetical, thus ruling out answers A & B.

____5. Which of the following is the best statement concerning models?

A. A model is a small scale version of a scientific theory.
B. A model is a visualization which helps to clarify a theory.
C. A model is usually used by scientists to prove scientific laws.
D. To a scientist, a model is a convenient way to represent reality.

____6. The steps described below have often been ascribed to "scientific method"

(1) Planning and conducting a series of experiments.
(2) Reaching a conclusion.
(3) Recognition of a problem.
(4) Proposal of a possible explanation.
(5) Examination of available information.

Which of the following represents the order in which these steps are usually said to be followed?

A. (1)(3)(2)(5)(4)
B. (3)(4)(1)(5)(2)
C. (5)(1)(4)(3)(2)
D. (3)(5)(4)(1)(2)

____7. Which of the following accurately reflects current thinking regarding a "scientific method"?

A. Scientists are more likely to follow the scientific method than people in other occupational groups.
B. The steps of the scientific method should be followed in logical progression to assure success in experimentation.
C. Two or more scientists attacking the same problem will probably proceed in essentially the same manner.
D. Scientists use a variety of methods that combine curiosity with imagination in seeking answers to problems.

____8. Of the following, which is the best statement regarding science and technology?

A. The production of a TV set is an example of technology, while production of a lunar landing craft is an example of science.
B. Science is a search for knowledge; technology makes practical use of that knowledge.
C. Science provides man with the means for leading a better life; technology is concerned chiefly with mechanical problems.
D. A person running blood tests in a hospital lab is engaged in scientific work, a person running soil sample tests is engaged in technology.

___9. Which of the following statements best draws the distinction between the use of the term, element, by the ancient Greeks and modern scientists?

A. The ancient Greeks knew only four elements, while modern scientists recognize over 100.
B. The ancient Greeks included air and fire on their list of elements, but modern scientists classify these as compounds.
C. The ancient Greeks thought of elements as principles or properties, but modern scientists think of them as unique basic substances.
D. The ancient Greeks thought that elements are composed of atoms, but modern scientists think they are composed of molecules.

____10. Which of the following statements most accurately describes the alchemical period?

A. Many technological processes were rather sophisticated; these processes sometimes revealed information about the physical world.
B. The pursuit of science was at a much higher level than technology. The technology had to wait until the appropriate scientific discoveries were made.
C. Science and technology enjoyed about the same relationship that they do today, basic research followed by practical application.

____11. The first statement of what could be termed a modern view of the concept of an element

A. was contained in the atomic theory of John Dalton (about 1805).
B. came out of the alchemical period.
C. was contained in the writings of Paracelsus (about 1530).
D. occured in the writings of Robert Boyle (about 1660).

12. Select the names from the right hand column which match the descriptions below:

___(1) conducted the famous experiment where alpha particles were scattered by gold foil, thus indicating that the nucleus of an atom is very small, and that an atom is mostly empty space.

___(2) One of the first to place an emphasis on quantative measures in science; formulated the law of conservation of mass.

___(3) Credited with the first periodic table.

___(4) Developed a theory of chemical atomism.

A. Aston
B. Dalton
C. Lavoisier
D. Moseley
E. Mendeleyev
F. Priestley
G. Roentgen
H. Rutherford

____13. Consider the following four statements about the value of the periodic table:

(1) It caused scientists to search for explanations for the regularities shown by the table.
(2) Open spaces in the original table allowed Mendeleyev to predict the existence of undiscovered elements.
(3) It allows scientists to make predictions about the properties of an element by its position on the table.
(4) It provides a rational explanation for the physical properties of the elements.

Question 13 continued on next page

Which of the above statements are correct?
A. only (1) and (2)
B. only (2) and (3)
C. only (1) (2) and (3)
D. only (2) (3) and (4)

14. Choose the term from the right hand column which satisfy the description given below

____(1) a nuclear particle with no electrical charge

____(2) an atom that has lost an electron

____(3) identical with a helium ion.

____(4) a nuclear particle with a positive charge.

____(5) the total number of nuclear particles in an atom.

A. alpha particle
B. atomic number
C. electron
D. mass number
E. negative ion
F. neutron
G. positive ion
H. proton

15. Answer the following items for the isotope, $^{37}_{17}Cl$

____(1) number of protons

____(2) number of neutrons

____(3) atomic number

____16. What would be the metric system equivalent for an object 15 inches in length?
A. about 6 centimeters
B. about 38 centimeters
C. 50 centimeters
D. about 100 centimeters

____17. If you purchased 500 grams of ground beef, how many pounds would you have?

A. 5
B. about 15
C. about 2.2
D. about 1.1

____18. Using a metric ruler extend line a to 5 cm; extend line b to 9 cm; complete the triangle by drawing line c, connecting the ends of lines a and b. How long is line c?

19. When a candle burns in a closed container, the flame goes out before all the wax is used up. Consider these explanations in answering the following questions:

A. the phlogiston in the air was used up, therefore the flame went out.
B. the carbon dioxide produced, being denser than air, filled the container from the bottom up and "smothered" the flame.
C. the air had become saturated with phlogiston and could accept no more, so the burning ceased.
D. the amount of oxygen in the container dropped below 50%; therefore the burning ceased.
E. the phlogiston in the candle was depleted; so the flame went out.

_____(1) Which of the statements above could be attributed to a phlogistonist?

_____(2) Which of the statements above could be attributed to a modern scientist?

____20. Which of the following reactions is <u>not</u> exothermic?

A. natural gas burning in air.
B. the decomposition of mercuric oxide by heating.
C. the combustion of gasoline in an automobile engine.
D. the burning of a candle in limited air.

____21. Suppose you wish to confirm the law of conservation of mass in the case of a burning candle. Which of the following would be the best procedure?

A. Determine the mass of the candle; then burn the candle in a closed container until it is extinguished; remove the candle and determine its mass.
B. Determine the mass of the candle on a balance pan, then light it and observe it as it burns on the balance pan.
C. Determine the mass of a closed system which includes the candle; burn the candle until it is extinguished; again determine the mass of the system.

22. Considering health and economics, label the following situations as desirable (D) or undesirable (U).

____ (1) a kitchen range adjusted so that there is a large fuel to air ratio.

____ (2) Breathing air which has been enriched with nitrogen.

____ (3) an automobile engine with a high capacity air intake.

____23. Which of the following is the most accurate comparison of the processes of combustion, slow oxidation, and respiration?

A. they are all similar processes, varying primarily in rate.
B. they are all similar processes, varying primarily in the type of products formed.
C. Combustion and slow oxidation have a lot in common, but respiration is an exothermic process.
D. they are each uniquely different processes, with different rates, products, etc.

____24. Which of the following groups of substances could not be the result of a combustion or respiration reaction?

A. C and CH_4
B. CO_2 and H_2O
C. CO and H_2O
D. CO_2 and CO

____25. A piece of wood burns in pure oxygen. Which of the following is the most likely description of the products.

A. C and H_2O

B. CH_4 and CO_2

C. CO and H_2O

D. CO_2 and H_2O

26. Provide the proper coefficients to balance the following equation:

A. $C_2H_6 + O_2 \longrightarrow CO_2 + H_2O$

27. The balanced equation below represents the photosynthesis process. If we had enough CO_2 and water reacting to produce 18 molecules of oxygen (O_2), how many carbohydrate molecules ($C_6H_{12}O_6$) would be produced?

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

A. 2
B. 3
C. 6
D. 18

28. Statement (1) to (4) below illustrate one of the basic laws of chemistry. For each statement select from the following list the most appropriate law:

A. the law of conservation of mass.
B. the law of definite composition.
C. the law of multiple proportions.

_____ (1) two well known compounds of sulfur are SO_2 and SO_3.

_____ (2) Sodium chloride, recovered from sea water, is found to contain 39.4% sodium. Sodium chloride prepared in the laboratory also contains 39.4% sodium.

_____ (3) the mass ratio of hydrogen to carbon in CH_4 is 1:3. The ratio in C_3H_6 is 1:6.

_____ (4) Twelve grams of carbon is burned ($C + O_2 \longrightarrow CO_2$) Thirty two grams of oxygen is consumed in this reaction which produces 44 grams of CO_2.

29. For each of the statements (1 to 4) below identify whether it is consistent with Dalton's atomic theory, the modern atomic theory, or both

A. consistent with Dalton's theory.
B. consistent with modern atomic theory
C. consistent with both A and B.

____(1) All sulfur atoms are identical.

____(2) Atoms retain their characteristic mass in chemical reactions.

____(3) All sulfur atoms have 16 protons in their nuclei.

____(4) The three natural isotopes of oxygen are oxygen 16, 17, and 18.

_____30. The standard for the modern atomic mass scale is

A. the carbon 12 isotope
B. the oxygen 16 isotope
C. hydrogen
D. the natural mixture of oxygen isotopes

31. Methane gas, the principal ingredient in natural gas, is composed of carbon and hydrogen. An analysis shows that for every 12 grams of carbon in methane 4 grams of hydrogen are present.

____(1) If a sample of methane contains 16 grams of hydrogen, how much carbon would it contain?

____(2) How much hydrogen would 32 grams of methane contain?

32. Imagine that you are a sixth grade science teacher and have been given the task of recommending 1 or 2 students for a special science program, based on your observations of their scientific investigations in your class. Name and in one or two sentences describe the 3 most important characteristics you would consider in making this selection.

A.

B.

C.

33. Mr. Jones stated, "Progress in chemistry depends more than anything else on the availability of necessary instruments and techniques," Cite and briefly describe an example which may be used to defend his view.

34. In light of modern knowledge, the phlogiston theory must be considered an imperfect theory of combustion and calcination. Discuss the advantages and disadvantages of having such a theory.

Name:

Number:

_____1. When nitrogen combines with hydrogen to form ammonia, 1 volume of nitrogen reacts with 3 volumes of hydrogen to produce 2 volumes of ammonia. This illustrates

A. Boyles Law
B. Charles Law
C. Avogadro's Theory
D. Gay-Lussac's Law

_____2. For the statement in the preceding question to hold true, which of the following conditions must exist?

A. All volumes must be measured at the same temperature and pressure.
B. All volumes must be measured at the same temperature. The pressure is an insignificant factor.
C. All volumes must be measured at standard temperature. The pressure is an insignificant factor.
D. All volumes must be measured at the same pressure. The temperature is insignificant.

_____3. The balanced equation for the formation of ammonia (mentioned in question 1) is:

$$N_2 + 3\,H_2 \longrightarrow 2\,NH_3$$

If 12 liters of hydrogen react completely with nitrogen to form ammonia, how much nitrogen is consumed?

A. 1 liter
B. 3 liters
C. 4 liters
D. 8 liters
E. 12 liters

_____4. In the situation described in the preceding question, what volume of ammonia would be produced?

A. 1 liter
B. 3 liters
C. 4 liters
D. 8 liters
E. 12 liters

_____5. One volume of nitrogen (N_2) combines with two volumes of gas X to produce two volumes of gaseous NX_2. How many atoms were present in a molecule of gas X?

A. 1
B. 2
C. 3
D. 4
E. 5

____ 6. The volumes of gaseous reactants and products have a small whole number relationship. Which of the following statements helps to explain why this is so?

A. The volume of a sample of gas is inversely proportional to the pressure.
B. The volume of a sample of gas is directly proportional to the temperature.
C. At standard temperature and pressure, the volume occupied by 1 mole of any gas is 22.4 liters.
D. Equal volumes of gases, under the same conditions of temperature and pressure, contain equal number of molecules.

____ 7. One liter of a particular gas has a mass of 1.12 grams at standard temperature and pressure. What is its molecular mass? (1 liter of oxygen (O_2) at S.T.P. has a mass of 1.43g)

A. 20
B. 25
C. 30
D. 32
E. 40

____ 8. Avogadro's Theory was proposed about 1811. It was not widely accepted for nearly 50 years. This reluctance to accept the theory was because

A. The chemists of the time could not readily accept the idea that two atoms of the same element could form a molecule.
B. The chemists of the time mistakenly thought gas molecules were close to each other, making it difficult to explain equal numbers of molecules of different sizes occupying equal volumes.
C. There was no precise method of measuring gas volumes in the early 19th century, thus making verification impossible.
D. Both answers A and B are correct; C is incorrect.
E. Both answers B and C are correct; A is incorrect.

Statements A through E may all be considered as postulates of the caloric fluid theory. Choose the one which <u>best</u> interprets the situation in questions 9 through 12.

A. Heat is an invisible, fluid substance, with no color or odor.
B. This caloric fluid occupies space and has mass.
C. Caloric fluid (heat) flows spontaneously from regions where it is highly concentrated to regions where it is less concentrated (from warmer to cooler regions).
D. Caloric fluid enters some solids, liquids, and gases more readily than others.
E. The addition of caloric fluid to matter increases the disorder in the arrangement of the particles of the matter. Matter changing from a more ordered to a less ordered state (solid to liquid, liquid to gas) is absorbing caloric fluid; matter changing from a less ordered to a more ordered state is releasing caloric fluid.

_____ 9. An ice cube is placed in a glass of tea at room temperature. The tea becomes cooler.

_____10. The plastic handle on a saucepan can be safely touched with your hand; you need a hotpad to hold onto a metal handle on a pan.

_____11. A pan of water boiling on a burner.

_____12. Most objects increase in volume when they are heated.

Statements A through E may all be considered as postulates of the kinetic molecular theory. Choose the one which best interprets the situations described in questions 13 through 19.

A. Gases are composed of molecules in ceaseless, random motion.
B. Collisions of gas molecules with each other and with the walls of a container are perfectly elastic.
C. Gas molecules are very small compared to the space they occupy.
D. As the temperature is increased, molecules move faster.
E. There is no appreciable attractive force between molecules in the gaseous state.

_____13. A bottle of perfume is left unstopped. Its odor can soon be detected at a considerable distance.

_____14. Providing there is no leak, a balloon will remain inflated indefinately.

_____15. While it is very difficult to compress liquids, gases may be compressed greatly.

_____16. Automobile tires will have a higher pressure following sustained driving, than when they have been stationary for a long period.

_____17. Steam boilers should be provided with safety valves.

_____18. Water will evaporate much faster on a warm day than on a cool day.

_____19. A blind man can tell when he is passing a bakery.

_____20. Twenty calories of heat is added to two grams of water at 20° C. The final temperature of the water is

A. 22° C
B. 30° C
C. 32° C
D. 40° C

_____21. You have a sample of 100 grams of water at 40° C. It is heated on a burner to 50° C. How many calories of heat were added?

A. 10 calories
B. 100 calories
C. 1,000 calories
D. 10,000 calories

Statements (1) through (4) represent results of investigations or observations of common phenomena.

(1) There is no evidence of a change in mass when objects are heated or cooled.
(2) When an ice cube is heated, it melts.
(3) Water evaporates much faster on a warm day than on a cool day.
(4) Heat can be continuously produced by rubbing two objects together.

____22. Which of the statements above cannot be readily interpreted by the caloric fluid theory and have led to the acceptance of the kinetic theory?

A. (1) and (2) only
B. (1) and (3) only
C. (1) and (4) only
D. (2) and (3) only
E. (3) and (4) only

____23. A gas is confined in a rigid steel container so that its volume is constant. As the temperature is increased, the pressure exerted by the gas will

A. increase
B. decrease
C. remain the same

____24. The pressure-volume relationship expressed by Boyles' Law can be explained by the kinetic molecular theory as follows:

A. When more pressure is applied to a gas, a greater volume dissolves in a liquid.
B. When the volume of a gas is decreased, the molecules are closer together causing more frequent collisions with the walls of the container.
C. When the volume of a gas is increased, the molecules are further apart and will move faster.

____25. A quantity of methane gas occupies 18 liters when the pressure is 1 atmosphere. What volume will it occupy if the pressure is increased to 9 atmospheres? (Assume constant temperature.)

A. 1 liter
B. 2 liters
C. 3 liters
D. 12 liters
E. 18 liters

____26. A quantity of oxygen occupies a volume of 3 liters at 200°. on the Kelvin scale. What volume will it occupy if the temperature is doubled? (Assume constant pressure)

A. 1.5 liters
B. 3 liters
C. 4.5 liters
D. 6 liters

_____27. The temperature-volume relationship expressed by Charles Law can be explained by the kinetic molecular theory as follows:

A. When the temperature of a gas is increased, the molecules have an increased average velocity.
B. When the temperature of a gas is increased, a greater volume of the gas dissolves in a liquid.
C. When gas molecules are packed closer together they will have more collisions with each other. The energy lost in these collisions will account for a lower temperature.

_____28. Providing that they are all at the same temperature, which of the following types of gas molecules will have the greatest velocity?

A. CH_4
B. CO_2
C. O_2
D. H_2

_____29. A weather balloon occupies a volume of 5 cubic feet when it is released. What would you predict for its volume at 20,000 feet.

A. less than 5 cubic feet
B. 5 cubic feet
C. more than 5 cubic feet

For the following problems you may use these values for atomic masses:

Hydrogen 1	Oxygen 16
Carbon 12	Sulfur 32
Nitrogen 14	

_____30. How many molecules are contained in 28 grams of carbon monoxide (CO)?

A. 1×10^{23}
B. 3×10^{23}
C. 6×10^{23}
D. 12×10^{23}

_____31. A sample of sulfur dioxide has (SO_2) has a mass of 16 grams. At standard temperature and pressure this sample would occupy a volume of

A. 5.6 liters
B. 11.2 liters
C. 22.4 liters
D. 44.8 liters

____32. Which of the following relates to a specific number of atoms?

A. atomic mass
B. gram atomic mass
C. molecular mass
D. gram molecular mass

____33. If you wanted to take 1 mole of carbon atoms, what mass of carbon would you take?

A. 1 gram
B. 6 grams
C. 12 grams
D. 16 grams
E. 24 grams

____34. If you wanted to take 1 mole of ethane (C_2H_6), what mass would you take?

A. 1 gram
B. 18 grams
C. 25 grams
D. 30 grams
E. 36 grams

____35. How many moles would you have if you had 51 grams of ammonia (NH_3)?

A. 1 mole
B. 2 moles
C. 3 moles
D. 4 moles
E. 5 moles

Benzene (C_6H_6) burns according to the following equation:

$$2\ C_6H_6 + 15\ O_2 \longrightarrow 6\ H_2O + 12\ CO_2$$

____36. How many moles of carbon dioxide are formed for each mole of benzene burned? (see equation above)

A. 1
B. 4
C. 6
D. 12

____37. How many moles of oxygen are needed for the combustion of 4 moles of benzene? (see equation above)

A. 7.5
B. 15
C. 30
D. 45

____38. If 1 mole of benzene is burned, how many grams of water are produced? (see equation above)

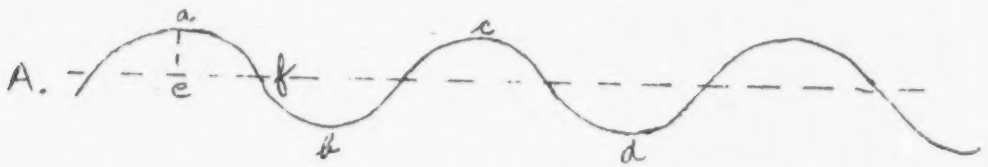
A. 18 grams
B. 36 grams
C. 54 grams
D. 72 grams
E. 108 grams

A-I Physical Science 111 UNIT III

Name:

Number:

In answering questions 1-4 refer to the waves represented below.



_____1. In drawing A above a wave length is the distance between
- A. a and f
- B. a and b
- C. a and c
- D. a and d
- E. a and e

_____2. Assuming that waves A and B have the same velocity which wave has the higher frequency?

_____3. If the waves represented by A and B were magnified representations of red light and violet light which would represent the violet?

_____4. Which of the waves represented by A and B is associated with the greater energy transition by electrons?

_____5. Which of the following waves represents the most energy?
- A. red light
- B. orange light
- C. green light
- D. violet light

_____6. Electricty is passed through a neon filled tube. When the resulting light is viewed through a spectroscope several distinctive lines are observed. What is the origin of these lines?

- A. The spectral lines result from the radiation given off as electrons travel in circular paths around the nuclei of neon atoms.
- B. The spectral lines result from interference between electrons traveling in different orbital paths around neon nuclei.
- C. The spectral lines result from energy given off as electrons move from higher to lower energy levels in the neon atoms.

_____ 7. According to the postulates of the Bohr theory the maximum number of electrons in each of the first four shells or energy levels is

A. 2, 8, 18, 32
B. 2, 8, 16, 36
C. 2, 4, 8, 16
D. 2, 5, 10, 20

_____ 8. A particular atom has 2 electrons in the K shell and 5 electrons in the L shell. It would be an atom of

A. lithium (Li)
B. boron (B)
C. nitrogen (N)
D. fluorine (F)

_____ 9. The number of electrons in each successive energy level for a sodium atom (Na) is

A. 2, 6, 3
B. 2, 8, 1
C. 2, 9
D. 2, 8, 8, 1

_____10. The number of electrons in the outer shell (valence shell) of Iodine atoms (atomic number 53) is

A. 1
B. 2
C. 5
D. 7

_____11. Which of the following elements has an outer shell (valence shell) containing three electrons?

A. magnesium (no. 12)
B. phosphorus (no. 15)
C. calcium (no. 20)
D. gallium (no. 31)

_____12. In the space below, draw a Bohr model structure representing an atom of aluminum (atomic number 13).

Consider statements (1) to (3) in answering question 13 below.

(1) Both the Bohr model and wave model are ways to visualize what real atoms might be like.

(2) The Bohr model was useful for many years, but most of the postulates of the Bohr theory have now been found to be incorrect.

(3) The principal difference in the two atomic models is the way in which the location of electrons is visualized.

_____13. Which of the statements above concerning atomic models is correct?
A. only statement (1)
B. only statements (1) and (2)
C. only statements (1) and (3)
D. only statements (2) and (3)
E. all three statements

14. In the space below make drawings to represent an s orbital a p orbital and a p subshell. Label them.

_____15. The maximum number of electrons in a p <u>orbital</u> is

A. 1
B. 2
C. 3
D. 4

_____16. The maximum number of electrons in a full p <u>subshell</u> is

A. 1
B. 2
C. 3
D. 6

_____17. The electron configuration for fluorine (atomic number 9) is

A. $1s^2 2s^2 2p^5$

B. $1s^2 2s^7$

C. $1s^2 2s^2 2p^3$

D. $1s^2 2p^7$

_____18. Which of the following elements has two s electrons and three p electrons in the outer shell?

A. potassium (no. 19)
B. germanium (no. 32)
C. arsenic (no. 33)
D. bromine (no. 35)

_____19. The element which has the electron configuration $1s^2 2s^2 2p^6$ is

A. carbon (no. 6)
B. oxygen (no. 8)
C. neon (no. 10)
D. magnesium (no. 12)

_____20. The number of electrons that may be found in the outermost energy level (valence shell) of any atom varies

A. from 1 to 6
B. from 1 to 8
C. from 2 to 6
D. from 2 to 10
E. from 1 to 10

_____21. The type of bonding which results when one type of atom transfers electrons to another type of atom is

A. ionic bonding
B. covalent bonding
C. hydrogen bonding
D. Van der Waals bonding

_____22. When electrons are shared unequally between two atoms, the usual result is the formation of

A. positive ions
B. negative ions
C. polar molecules
D. nonpolar molecules

Predict whether ionic bonding (I) or covalent bonding (C) is likely to occur in bonds formed between the following pairs of elements (questions 23 to 26).

_____23. magnesium (no. 12) and chlorine (no. 17)

_____24. sulfur (no. 16) and oxygen (no. 8)

_____25. phosphorus (no. 15) and chlorine (no. 17)

_____26. sodium (no. 11) and bromine (no. 35)

_____27. At ordinary temperatures ionic compounds are

A. gases
B. liquids
C. crystalline solids
D. amosphous solids

_____23. The basic entity in a compound resulting from covalent bonding is

A. a positive ion
B. a negative ion
C. either a positive or a negative ion
D. a molecule

_____29. The attractive force between water molecules is called

A. ionic bonding
B. covalent bonding
C. hydrogen bonding
D. metallic bonding

_____30. Water is a liquid at ordinary temperatures, while many compounds with molecules of comparable molecular mass, such as methane (CH_4), ammonia (NH_3) and carbon dioxide (CO_2), are gases. This would indicate that at a given temperature

A. there is a greater attractive force between water molecules than between the molecules of the other compounds.
B. the average energy of water molecules is greater than the average energy of the molecules of the other compounds.
C. molecules of gases like methane have a repulsive force between them, while water molecules are attracted to each other.

_____31. Which of the following statements offers a partial explanation for the phenomenon mentioned in the preceding question?

A. water molecules are polar, the others mentioned are nonpolar.
B. Water molecules are nonpolar; the others mentioned are polar.
C. There is a more even distribution of electrical charge in water molecules than in the other molecules mentioned.
D. Water molecules are more efficient at absorbing energy than the other molecules mentioned.

Draw electron dot structures for the entities listed in questions 32 to 36.

32. a potassium atom (no. 19)

33. a potassium ion

34. a bromine atom (no. 35)

35. a bromide ion

36. a hydrogen sulfide (H_2S) molecule

A-I Physical Science UNIT IV

Name _____

Number _____

Items 1 through 5 are statements about organic chemistry. For each item choose the most appropriate response from the following:

A. Consistent with the description of organic chemistry commonly accepted in 1800; inconsistent with the modern view.
B. Consistent with the modern description of organic chemistry; inconsistent with the earlier (1800) description.
C. Consistent with both the modern description and the earlier (1800) description of organic chemistry.
D. Inconsistent with both the modern and the earlier (1800) description of organic chemistry.

____1. Plants and animals produce organic compounds.

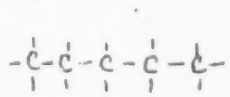
____2. All those compounds with low melting points (below 100° C) are organic compounds. Those with high melting points (above 100° C) are not.

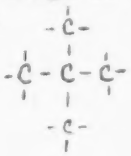
____3. Organic compounds may be synthesized from other compounds obtained from plant, animal, and mineral sources.

____4. Most organic compounds will char, burn, vaporize, or explode when heated. Most inorganic compounds are stable when heated.

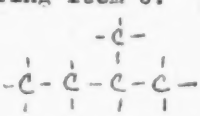
____5. Organic compounds may be produced only under the influence of a vital force, which is exerted only by living organisms.

Consider structural formulas I through IV in answering item 6.

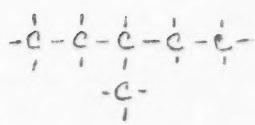




II



III



IV

____6. Which of the structures above are isomeric with each other?

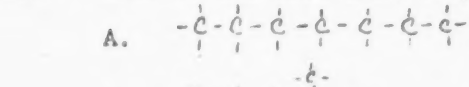
A. I and II only.
B. II and III only.
C. I and IV only.
D. I, II, and III only.
E. I, II, III, and IV.

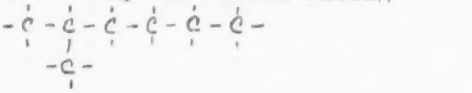
____7. Which of the following has the largest number of isomers?

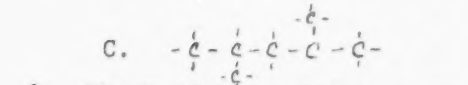
A. C_6H_{14} B. C_4H_8

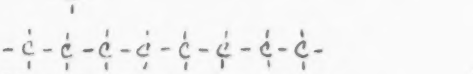
C. C_4H_{10} D. C_3H_{13}

____8. Which of the following compounds would have the highest octane rating?

A. 

B. 

C. 

D. 

____9. Which of the following are the most desirable compounds for use in gasoline?

A. Straight chain compounds containing from 1 to 5 carbon atoms.
B. Branched chain compounds containing from 1 to 5 carbon atoms.
C. Straight chain compounds containing from 6 to 9 carbon atoms.
D. Branched chain compounds containing from 6 to 9 carbon atoms.

____10. Which of the following chain compounds contains a double bond?

A. C_2H_6 B. C_4H_8

C. C_5H_{12} D. C_7H_{16}

____11. Which of the following statements is correct?

A. Coal tar is rich in ring-type hydrocarbons; petroleum is rich in chain-type hydrocarbons.
B. Petroleum is rich in ring-type hydrocarbons; coal tar is rich in chain-type hydrocarbons.
C. While both coal tar and petroleum contain some ring-type hydrocarbons, they have more chain-type hydrocarbons.
D. While both coal tar and petroleum contain some chain-type hydrocarbons, they have more ring-type hydrocarbons.

____12. Which of the following statements is most consistent with Kekule's view regarding earlier scientific workers and their ideas?

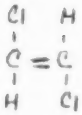
A. Our present theories are built on the ruins of earlier theories.
B. For the most part, scientific progress in a given time span, is built upon the theories of earlier workers.
C. If one reads all of the works of earlier investigators, he will himself become a good investigator.
D. Considering the sophistication of recent theories, the average intelligence level of the men who formulate theories must be improving over the centuries.

____13. Naturally occurring polymers include
A. protein, starch, and wool.
B. cotton, wool, and styrofoam.
C. wood, teflon, and rubber.
D. cotton, silk, and nylon.

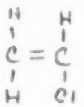
____14. Synthetic polymers have been used primarily for

A. fabrics, cooking oils, and structural materials
B. plastics, fabrics, and rubber replacements
C. structural materials, fabrics, and automobile engines
D. plastics, rubber replacements, and automobile engines

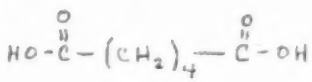
Refer to structural formulas I through VI in answering questions 15 through 17.



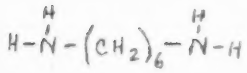
I.



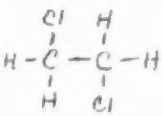
II.



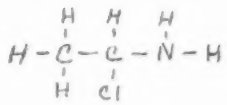
III.



IV.



V.

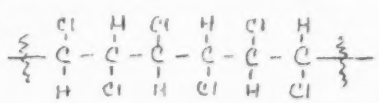


VI.

____15. Which of the molecules shown could serve as monomers for addition polymerization?

A. I and II only
B. III and IV only
C. V and VI only
D. I, II, V, and VI only

____16. The following structure represents a fragment of a polymer:



Which of the structures from the group shown above could serve as the monomer in preparing this polymer?

A. I only
B. II only
C. V only
D. VI only
E. either I or VI
F. either II or V

____17. You wish to prepare a polymer by the condensation process. Your choice from the list of monomers should be:

A. III only
B. IV only
C. I and II
D. III and IV
E. III and VI

____18. The principal sources of raw materials (monomers) for producing synthetic polymers are

A. living plants and animals
B. living plants and coal
C. petroleum and wood
D. animal fat and petroleum
E. petroleum and coal

____19. Which of the following structural features are found in both soaps and detergents?

A. They both are composed of polar molecules.
B. They both are composed of nonpolar molecules.
C. They both have a long nonpolar molecule with a polar group at one end.
D. They both have a long nonpolar molecule with polar groups at both ends.

____20. Soap may be prepared by reacting

A. animal fat and lye.
B. vegetable oil and glycerin.
C. animal fats and salt.
D. either fats or oils and glycerin.

____21. Hard water is a term applied to water which

A. contains phosphates.
B. contains iron, calcium, or magnesium ions.
C. contains sodium or potassium ions.
D. has a high degree of acidity.

____22. Which of the following is most likely to promote the growth of algae and plants in a lake?

A. water that is very alkaline.
B. water that contains a fairly high concentration of sodium carbonate.
C. water that has a high degree of acidity.
D. water that contains a fairly high concentration of nitrogen and phosphorus.

____23. The phosphorus compounds included in some detergents act primarily as

A. builders, to tie up ions of iron and calcium.
B. surfactants, to emulsify and float away oil-dirt mixtures.
C. bleaching agents, to whiten some colored compounds.
D. wetting agents, to allow the water to enter small openings in cloth.

____24. Detergents were originally developed and used because

A. The supply of raw materials for soap making was becoming exhausted.
B. Detergents are much cheaper to produce than soap.
C. Detergents do not form a sticky precipitate in hard water, as do soaps.
D. Detergents work equally well in hard and soft water.

You want to do your part in preserving the environment. While shopping for a laundry product you find the following information on the labels of products:

I. Gets your clothes "whiter than white."
II. Lower phosphate content
III. 12.2% phosphates
IV. 6.5% phosphates; no other chemical additives
V. no phosphates added!

____25. Based solely on the information given, which product should you buy?

A. I, because you will get the cleanest wash and it doesn't say anything about including polluting chemicals.
B. II., because this product may have a lower phosphate content than I, III, and IV and a certain amount of phosphate is needed.
C. V., This is the only product you can use and be certain that you aren't adding phosphorus to the environment.
D. IV., This one has the lowest stated phosphate content except V. (V might contain other more harmful additives.)

____26. In 1971 some small companies began marketing detergents with no phosphates added. The principal disadvantage which prevents widening this trend is

A. These detergents have precipitating builders in place of phosphates. These make the water dangerously alkaline.
B. The big companies have large sums of money invested in plants to produce phosphates. They would go bankrupt if they abandoned the use of phospahtes.
C. The precipitating builders used in place of phosphates are quite expensive. The average housewife will not buy these products beaause of the cost.

27. Suppose that you have been hired by a large corporation to head their research division. They have been spending almost all of their research money on developmental research. How could you convince them that they should spend a portion of this money on basic research? Cite two arguments you could use. (You may mention specific examples from your reading to clinch your point.)

A.

B.

23. Suppose that you are working for a large manufacturer of laundry products. You are asked to show why a total ban on phosphates should not go into effect immediately. What are two arguments you might use to do this?

A.

B.

29. Briefly discuss the question "Is science good or evil?" You may use examples from your readings.

30. Finding a solution to a social problem involving scientific knowledge, such as the phosphate problem, may require assuming some responsibility and taking suitable action by the government, by industry, by the general public, and by scientists.

____(1) Who do you think should take the primary responsibility for finding a solution to social problems involving scientific knowledge?
____ Select two from the following list.

A. the government
B. industry
C. the general public
D. the scientists

(2) Explain why you think the primary responsibility rests with the two institutions or groups you selected in question one, rather than with the other two.

(3) Suggest two or more specific actions that are appropriate to take by each of the institutions or groups you selected in question one.

name of institution or group	Action they should take

APPENDIX D

ADDITIONAL TABLES

Table 18. Student Behavior Categories, Correct Responses, and Incorrect Responses for Pre-Test and Post-Test POSII Items

Table 19. Instructional Objectives, Correct Responses, and Incorrect Responses for Unit I SCT Items

Table 20. Instructional Objectives, Correct Responses, and Incorrect Responses for Unit II SCT Items

Table 21. Instructional Objectives, Correct Responses, and Incorrect Responses for Unit III SCT Items

Table 22. Instructional Objectives, Correct Responses, and Incorrect Responses for Unit IV SCT Items

Table 23. Identification of Scales by Items for the SAOSS

TABLE 18

STUDENT BEHAVIOR CATEGORIES, CORRECT RESPONSES, AND INCORRECT RESPONSES FOR PRE-TEST AND POST-TEST POSII ITEMS

Student Item	Behavior Category	Pre-test Correct	Pre-test Incorrect	Post-test Correct	Post-test Incorrect
1.	B.1	8	20	17	11
2.	D.3	21	7	23	5
3.	D.3	18	10	16	12
4.	B.1	17	11	25	3
5.	B.3	10	18	18	10
6.	B.3	14	14	16	12
7.	B.4	10	18	24	4
8.	B.4	8	20	18	10
9.	B.4	11	17	11	17
10.	B.5	11	17	11	17
11.	B.5	24	4	25	3
12.	B.1	22	6	16	12
13.	D.3	6	22	3	25
14.	D.3	4	24	6	22
15.	D.3	11	17	11	17
16.	D.5	21	7	24	4
17.	D.5	23	5	22	6
18.	D.5	6	22	12	16
19.	E.5	10	18	6	22
20.	E.5	23	5	27	1
21.	E.5	12	16	11	17
22.	E.5	14	14	16	12
23.	E.5	13	15	14	14
24.	E.1	15	13	18	10
25.	B.3	9	19	16	12
26.	B.5	7	21	4	24
27.	E.3	6	22	9	19
28.	E.3	16	12	17	11
29.	E.5	8	20	14	14
30.	E.3	10	18	11	17
31.	D.1	18	10	24	4
32.	D.1	7	21	18	10
33.	D.1	7	21	5	23

TABLE 19

INSTRUCTIONAL OBJECTIVES, CORRECT RESPONSES, AND

INCORRECT RESPONSES FOR UNIT I SCT ITEMS

Item	Objective	Number Correct	Number Incorrect	Item	Objective	Number Correct	Number Incorrect
1.	1.A	20	8	15.(2)	2.H	24	4
2.(1)	1.A	16	12	(3)	2.H	25	3
(2)	1.A	28	0	16.	2.I	21	7
(3)	1.A	28	0	17.	2.I	15	13
(4)	1.A	25	3	18.	2.I	22	6
3.(1)	1.B	17	11	19.(1)	3.A	21	7
(2)	1.B	25	3	(2)	3.A	11	17
(3)	1.B	27	1	20.	3.B	18	10
(4)	2.A	15	13	21.	3.C,4.E	17	11
(5)	2.A	28	0	22.(1)	3.D	18	10
4.	1.C	18	10	(2)	3.D	25	3
5.	1.D	23	5	(3)	3.D	14	14
6.	1.F	21	7	23.	3.D	16	12
7.	1.G	21	7	24.	3.D	21	7
8.	1.H	28	0	25.	3.D	18	10
9.	2.B	18	10	26.	3.E	15	13
10.	2.C	4	24	27.	3.E	13	15
11.	2.D	23	5	28.(1)	4.A	14	14
12.(1)	2.E	20	8	(2)	4.A	17	11
(2)	2.E	21	7	(3)	4.A	20	8
(3)	2.E	25	3	(4)	4.A	17	11
(4)	2.E	23	5	29.(1)	4.B,4.C	23	5
13.	2.F	18	10	(2)	4.B,4.C	11	17
14.(1)	2.H	25	3	(3)	4.B,4.C	8	20
(2)	2.H	19	9	(4)	4.B,4.C	23	5
(3)	2.H	21	7	30.	4.F	16	12
(4)	2.H	24	4	31.(1)	4.G	23	5
(5)	2.H	25	3	(2)	4.G	14	14
15.(1)	2.H	26	2				

DISCUSSION ITEMS

Item	Instructional Objective	Possible Points	3 points	2 points	1 point	0 points
32.	1.J	3	15	12	0	1
33.	2.G	2		15	11	2
34.	3.H,4.D	2		20	4	3

TABLE 20

INSTRUCTIONAL OBJECTIVES, CORRECT RESPONSES, AND INCORRECT RESPONSES FOR UNIT II SCT ITEMS

Item	Instructional Objective	Number Correct	Number Incorrect	Item	Instructional Objective	Number Correct	Number Incorrect
1.	5.A	25	3	20.	6.D	19	9
2.	5.A	26	2	21.	6.G	21	7
3.	5.A	23	5	22.	6.C	19	9
4.	5.A	20	8	23.	6.D	21	7
5.	5.B	17	11	24.	6.E	22	6
6.	5.B	18	10	25.	6.F	23	5
7.	5.B	22	6	26.	6.F	21	7
8.	5.C	18	10	27.	6.E	17	11
9.	6.B	25	3	28.	6.B	16	12
10.	6.B	26	2	29.	6.D	22	6
11.	6.B	18	10	30.	7.A, 7.B	27	1
12.	6.B	25	3	31.	7.B	11	17
13.	6.B	19	9	32.	7.A	16	12
14.	6.B	19	9	33.	7.B	26	2
15.	6.B	24	4	34.	7.B	27	1
16.	6.B	25	3	35.	7.B	26	2
17.	6.B	22	6	36.	7.C	24	4
18.	6.B	24	4	37.	7.C	26	2
19.	6.B	21	7	38.	7.C	24	4

TABLE 21

INSTRUCTIONAL OBJECTIVES, CORRECT RESPONSES, AND

INCORRECT RESPONSES FOR UNIT III SCT ITEMS

Item	Instructional Objective	Number Correct	Number Incorrect	Item	Instructional Objective	Number Correct	Number Incorrect
1.	8.A	25	3	19.	9.F	27	1
2.	8.A	26	2	20.	9.D	26	2
3.	8.B	25	3	21.	10.A	25	3
4.	8.C	25	3	22.	10.E	18	10
5.	8.B, 8.C	25	3	23.	10.B	28	0
6.	8.D	24	4	24.	10.B	26	2
7.	8.E, 9.D	28	0	25.	10.B	25	3
8.	8.E	23	5	26.	10.B	25	3
9.	8.E	28	0	27.	10.D	20	8
10.	8.E	25	3	28.	10.A	22	6
11.	8.E	26	2	29.	10.E	18	10
12.	8.E	26	2	30.	10.E	19	9
13.	9.A	20	8	31.	10.E	15	13
14.	9.C	25	3	32.	10.F	26	2
15.	9.D	25	3	33.	10.F	20	8
16.	9.D	24	4	34.	10.F	25	3
17.	9.E	22	6	35.	10.F	18	10
18.	9.F	24	4	36.	10.F	19	9

TABLE 22

INSTRUCTIONAL OBJECTIVES, CORRECT RESPONSES, AND

INCORRECT RESPONSES FOR UNIT IV SCT ITEMS

Item	Instructional Objective	Number Correct	Number Incorrect	Item	Instructional Objective	Number Correct	Incorrect
1.	11.A, 11.B	20	8	14.	12.E	26	2
2.	11.A, 11.B	15	13	15.	12.C	24	4
3.	11.A, 11.B	23	5	16.	12.C	23	5
4.	11.A, 11.B	8	20	17.	12.C	20	8
5.	11.A, 11.B	22	6	18.	12.D	23	5
6.	11.C	23	5	19.	13.A	20	8
7.	11.D	28	0	20.	13.B	25	3
8.	11.F	25	3	21.	13.C	25	3
9.	11.G	16	12	22.	13.G	24	4
10.	11.L	14	14	23.	13.E	20	8
11.	11.K	17	11	24.	13.F	24	4
12.	11.J	22	6	25.	13.H	24	4
13.	12.A	23	5	26.	13.H	24	4

Item	Instructional Objective	Possible Points	4 pts.	3 pts.	2 pts.	1 pt.	0 pts.
27.	12.F	2			20	4	4
28.	13.J	2			22	3	3
29.	13.K	2			27	1	0
30.	13.I	4	22	2	1	0	3

TABLE 23

IDENTIFICATION OF ITEMS BY SCALES

FOR THE SAOSS

Item	Scale	Item	Scale	Item	Scale
1.	IV	12.	I	23.	I
2.	III	13.	IV	24.	IV
3.	II	14.	III	25.	III
4.	I	15.	II	26.	I
5.	IV	16.	I	27.	IV
6.	III	17.	IV	28.	IV
7.	II	18.	III	29.	IV
8.	I	19.	II	30.	III
9.	IV	20.	I	31.	III
10.	III	21.	IV		
11.	II	22.	III		

Scale I. Role of Science in the Culture and in Society

past, present, future
scientific inquiry as a means of gaining knowledge
benefits to society that accrue from science

Scale II. Support of Science as an Enterprise in the Nation

financial support
general or moral support
encouragement of youth to become scientists
support of science education for all

Scale III. Scientists as People

acceptability of scientists' general characteristics
personal preferences for scientists as friends, spouses, relatives, holders of public office
distorted image of science as suitable only for males

Scale IV. Personal Involvement with Science

as an area to study about
as an area of worth to the individual
from the viewpoint of a teacher

VITA

Glenn R. McElhattan was born on December 3, 1934 in Knox, Pennsylvania. He graduated from Knox High School in 1952 and received the Bachelor of Science degree from Clarion State College in 1956. From 1956 through 1959 he served as an artillery officer in the United States Marine Corps.

He taught chemistry, physics, and physical science at Rocky Grove High School, Franklin, Pennsylvania from 1959 to 1968. He received the Master of Science degree with a major in chemistry from Western Reserve University in 1963. He also completed graduate studies at Ohio Wesleyan University and Edinboro State College.

In 1968 Mr. McElhattan was appointed Assistant Professor of Chemistry at Venango Campus, Clarion State College. Since that time he has taught courses in Inorganic Chemistry, Physical Science and Teaching of Elementary Science. He began doctoral studies in the science education program at the University of Pittsburgh in 1968 and was certified as a doctoral candidate in March 1972. He was promoted to Associate Professor of Chemistry at Venango Campus in September 1972.